COMPARISON OF SHEAR BOND STRENGTH AFTER THERMOCYCLING, OF BRACKETS BONDED USING TWO DIFFERENT MOISTURE INSENSITIVE PRIMERS – AN IN VITRO STUDY

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CERTIFICATE

This is to certify that this dissertation titled **"COMPARISON OF SHEAR BOND STRENGTH AFTER THERMOCYCLING, OF BRACKET BONDED USING TWO DIFFERENT MOISTURE INSENSITIVE PRIMERS – AN IN VITRO STUDY"** is a bonafide record of work done by **DR.KAVITHA.R** under my guidance during her postgraduate study period between 2008–2011.

This dissertation is submitted to **THE TAMIL NADU Dr. M.G.R. MEDICAL UNIVERSITY**, in partial fulfillment for the degree of **Master of Dental Surgery** in Branch V –Orthodontics and Dentofacial Orthopedics.

It has not been submitted (partially or fully) for the award of any other degree or diploma.

Guide

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Introduction

INTRODUCTION

Direct bonding of orthodontic brackets has been advocated since 1960s[117]. With the introduction of newer adhesive systems as well as photosensitive (light-cured) restorative materials in dentistry, additional methods have been suggested to enhance the polymerization of the materials used, including layering and more powerful light-curing devices. Adhesives have evolved from acrylics to several other materials like epoxies, epoxy-acrylates[25,109,138]glass ionomer fluoride releasing cements,[158,171]to the present resin modified glass ionomer cements . In addition, other factors[147] can potentially contribute to the strength of the bond between the enamel and the orthodontic bracket, including

a. type of enamel conditioner,
b. acid concentration,
c. length of etching time,
d. composition of the adhesive,
e. bracket base design,
f. bracket material,
g. oral environment (presence of moisture) and
h. skill of the clinician.

Of all these moisture contamination after etching is the principle cause of early bond failure, and is an inherent problem all orthodontists face on a daily basis.

Over the years a great deal of attention has been paid to improve the acid-etching technique, primers and adhesives. Nonetheless, adhesive failures still exist because of contamination during bonding. Traditional bond materials must be applied in completely dry and isolated fields to achieve adequate bond strength. Hydrophilic bond systems have been an important development in orthodontic practice because many routine clinical procedures are not carried out under ideal conditions. In particular, it can be difficult to bond attachments to hard-to-reach places such as the gingival area, second molars, and partially erupted or impacted teeth[56,67,77,126]. In these cases, bonding failure is common, and rebonding, which consumes chair time and is a burden for both orthodontist and patient, becomes necessary[126]. In unsuccessful bonding procedures, most of the porosities produced by the enamel acid-etch procedure become plugged with moisture. As a result, resin penetration is impaired, and when insufficient numbers and lengths of resin tags form, bond strength is compromised[96,128,135]. Contamination of the enamel surface therefore necessitates the etching procedure to be repeated to ensure the adequate bonding of composites[96]. For this reason, several studies have evaluated the effects of contaminants like water, saliva, and blood on SBS[32, 67,126,169].

Earlier resins were manufactured of hydrophobic monomers, which performed well only in dry environments. Nowadays hydrophilic monomer(water soluble), such as 2-hydroxyethyl methacrylate (HEMA), 2-hydroxypropyl methacrylate (HPMA), 4 -hydroxybutyl methacrylate (HBMA) which are well known in restorative dentistry for dentine bonding, are used as adhesives for enamel bracket bonding. These substances allow for greater shear bond strength (SBS) on wet surfaces by enabling the composite to pass beyond the organic adhesive coating formed by moisture on the enamel's surface. Out of these HEMA is used commonly in moisture-insensitive primers (MIP) which perform adequately even in the presence of moisture. However, there are controversial reports on whether MIPs fulfil the requirements for bond strength in a dry environment[39,67]. **T**here are some studies which report that moisture contamination did not decrease the shear bond strength of composite resins with MIP when bonded to etched enamel[149]. Study by **Hara et al**[71] reported clinically acceptable bond strength under dry conditions for hydrophilic adhesive systems. A few studies showed that MIP with their respective adhesives is effective in both wet and dry fields[67,149].

Recent studies critically noted the inherent disadvantages of HEMA in adhesives which include:

1. HEMA retains water within the adhesive layer and adversely affects the mechanical strength[42];
2. 70% of HEMA can be hydrolyzed in acidic solutions within a week at 37°C[122];
3. HEMA provides low photopolymerization reactivity. Moreover, HEMA causes sensitized delayed allergic reaction[89].

Therefore, it could be anticipated that HEMA containing adhesive layers with high water absorption behaviour will possess low physical properties and result in poor bonding durability to the tooth substrates.

Glass ionomers were introduced to the profession 38 years ago and have been shown to be a very useful adjunct to restorative dentistry[171]. Glass ionomer cements, are materials made of calcium, strontium aluminosilicate glass powder (base) combined with a water-soluble polymer (acid)[114]. These cements possess certain unique properties that make them useful as adhesive materials, including.

1. Adhesion to tooth structure and base metals[78],
2. Anticariogenic properties due to release of fluoride[75],
3. Thermal compatibility with tooth enamel, and
4. Less enamel loss[41] from debonding compared to composites.

In recent years there have been considerable changes in the formulations, properties and handling properties of the glass ionomer cements for different clinical applications. Glass ionomer cements (GICs) were initially introduced as orthodontic bonding adhesives to take advantage of the fluoride-releasing capabilities of the material[72]. But the use of GICs in orthodontics was limited because of their lower bond strengths[19,38]. It is certain that no material is perfect, but with the current level of intensive research on glass ionomers, the deficiencies that exist seem to be eliminated or at least reduced, resulting in an ever – improving range of materials of this type.

Opal seal is ethanol based filled adhesive, comprised of 38% filled with substantial glass ionomer and nano-fillers and contains hydroxypropyl methacrylate (HPMA) which is a hydrophilic monomer. Opalseal has been claimed to be effective in wet environment. There are no studies comparing the shear bond strength of Transbond MIP (contains HEMA) and Opal seal along with conventional Transbond XT primer as control.

However, most in vitro studies on bond strength after saliva contamination did not use an artificial ageing procedure before testing, despite the fact that thermocycling of the specimens has been recommended to consider the durability of the bond. Thermal cycling is the in vitro process through which the adhesive resin and the tooth are subjected to temperature extremes compatible with the oral cavity[76].**Gale and Darvell**[64] pointed to the lack of consistency between the conclusions of different studies on the SBS of various adhesive systems following thermocycling[34,68]. They attributed this to the lack of standardization between the various thermocycling studies they reviewed. Such large variation between the thermocycling protocols led the International Organization for Standardization to provide specific criteria for conducting such tests to enable investigators and industry to interpret and compare results.

Therefore, the purpose of this study was to investigate the effectiveness of two moisture insensitive primers mainly Transbond MIP and Opal seal (used along with Transbond XT adhesive) with respect to conventional hydrophobic primer (Transbond XT) by comparing their shear-peel bond strengths after thermocycling and adhesive-failures locations after contamination with saliva.

Review of Literature

REVIEW OF LITERATURE

Literature has been reviewed under the following headings

- Studies on Bonding
- Studies on Glass Ionomer Cement
- Studies on Hydrophilic Primer
- Studies on Thermocycling

STUDIES ON BONDING

Buonocore M.G.et al[27] (1955), described a method of bonding acrylic resin filling material to enamel surface by etching the enamel with 85% phosphoric acid and phosphomolybdate oxalic acid treatment to alter enamel surface chemically, originating the ideas from industrial examples in which phosphoric acid was used to obtain better adhesion of paint and resin coatings to treated metal surfaces. He suggested that the increased adhesion could be due to an increase in the surface area amenable to mechanical adhesion brought about by acid etching.

Bowen et al[23] (1962) explored the possibility of using epoxy resins (diglycidyl ether of bisphenol A) mixed with silica particles. The in vitro results were promising, but the presence of moisture inhibited the polymerization process of epoxy resin. To overcome this problem, Bowen attached methylmethacrylate groups to the groups of the epoxy resin, thereby converting the epoxy resin to a dimethacrylate. The experiment outcome was successful and resulted in a new resin called Bisphenol. A glycedyl methacrylate or BISGMA or Bowen' resin.

Buonocore et al (1968)[29] studied the penetration of dental materials in to enamel surfaces with reference to bonding. They showed enhanced bonding to acid conditioned surfaces due to presence of prism-like tags. Poor bonding was associated with unconditioned surfaces.

George V. Newman et al[65](1973), commented on the bonding of attachments. He mentioned the various systems that have been used. After various studies he concluded that the ideal adhesive system should readily wet the tooth surface, polymerize in situ forming a firm bond with tooth structure on one side and the attachment on the other, especially in shear and tensile strength and be able to be removed by the orthodontist without destroying the integrity of enamel surface. The adhesive and attachment together should be aesthetic, adhere to enamel surface for an adequate treatment period, withstand the forces of mastication, arch wire stress, resist changes in ph from foodstuff and resist temperature changes and minimal leakage.

Silverstone et al[154] (1974) showed that etching the enamel surface with phosphoric acid resulted in a superficial etched zone and underlying porous zones. Depth of etched zone depended on the acid concentration, duration of etching, chemical composition of surface enamel etc.

Retief[137] (1975) commented that the depth of etch produced by 50% orthophosphoric acid was more than that obtained with orthophosphoric acid solution at any other concentration and produced comparable bond strength. The surface roughness of enamel etched with 50%orthophosphoric acid was greater than that obtained with more dilute acid solutions.

Reynolds et al[138] (1975) reported that clinically, the bonded brackets should be able to withstand forces generated by treatment mechanics and occlusion, yet allow easy debonding without damage to enamel. He has reported that maximum tensile bond strength of 5.9 to 7.9 Mpa would be adequate to resist treatment forces but added that in vitro tensile strength levels of 4.9 Mpa have proved clinically acceptable.

Thompson et al [140](1981) conducted an in vitro study to determine the amount of enamel lost during prophylaxis and during multiple bonding/debonding procedures. Both bristle brush and rubber cup were used with four different prophylactic pastes. The enamel loss with the bristle brush (14.38µ) was significantly greater than the loss with rubber cup (6.9 µ). No significant differences were associated with use of different pastes. Multiple bonding/debonding procedures were conducted with filled and unfilled resin adhesive. Total enamel loss was 71.5µ in the group bonded with a filled resin with prophylaxis and acid etching between bonds. This was significantly greater than the amount lost (22.3 µ) by the group bonded with the same resin without prophylaxis and acid etching between bonds. Total enamel loss was 45.4 µ in the group bonded with an unfilled resin with prophylaxis and acid etching between bonds. This was significantly greater than the amount lost (17.8 µ) by the group bonded with the same resin without prophylaxis and acid etching between bonds.

R. L. Bowen[23] (1962) stated that when equilibrated together, water and certain methacrylate monomer formulations form two phases, with the activity of water being equal with that of normal physiological saline solution. The proportions of hydrophilic and hydrophobic monomers were adjusted empirically to achieve this by measuring the solute concentrations in the aqueous phase by osmometric methods. Isotonic monomer formulations were pre- pared from a variety of chemically different monomers. Formulations of this type should be evaluated as vehicles for adhesion promoting coupling agents.

Artun and Bergland et al[9](1984) in a comparative study of conventional acid etching with 37%phosphoric acid and crystal growth conditioning with polyacrylic acid which contain residual sulphate ion, found that the latter has less bond strength and debonding was easier since the bond failure occurred at tooth adhesive interface. He introduced more complex means of defining the site of bond failure by adhesive remnant index (ARI). The score ranged between 0-3 and criteria for scoring is as follows:

- Score 0-no adhesive left on the tooth
- Score1-less than half of the adhesive left on the tooth
- Score2-more than half of the adhesive left on the tooth
- Score3-all the adhesive left on the tooth with distinct impression of the bracket mesh.

Fox et al[58] (1994) suggested a possible standard technique for bond strength testing. He suggested the following protocol for bond strength testing in orthodontics.

a. Surface of premolar enamel should be used on teeth extracted from adolescent patients for orthodontic reasons.
b. Teeth should be used after 1 month and before 6months of extraction.

c. After bonding, the specimens should be immersed in water for 24 hrs at 37°

d. Debonding should take place on an Instron or equivalent machine.

e. The point of application and direction of force should be same for all specimens.

f. At least 20 specimens should be used per test.

g. Site of failure should be reported.

h. Statistical analysis should include survival analysis to give a prediction of performance of the material. Bond strength should be quoted in either Newtons or Megapascals .

STUDIES ON GLASS IONOMER CEMENT

A. D. Wilson and B. E. Kent (1971)[171] introduced a new translucent cement, the product of the reaction between ion-leachable glass and an aqueous solution of polyacrylic acid is described. Its properties, with particular reference to dental applications, are reported and a proposed setting mechanism is advanced.

Chadwick SM, Gordon PH (1995)[35] Compared the fluoride release from a variety of orthodontic bonding agents. Fluoride release into de-ionized water was measured over a 20-week period. Material based on the fluoride exchange resin was also tested in a saline solution. Glass ionomer-based materials showed substantially greater fluoride release when compared with resin-based materials. The presence of anions (Cl-) did not improve the release from fluoride exchange resin. The results proved that Glass ionomer/resin hybrid material (Vitrabond) released the greatest amount of fluoride.

Millett et al[108] (1996) stated in his literature review that orthodontic bonding with glass ionomer cement is comparatively new. The purpose of this article is to review the current literature covering both *in vitro* and *in vivo* studies of various glass ionomer cements that have been used for orthodontic bonding. The review indicates that there is little support in the literature to suggest that the currently available conventional glass ionomer cements are suitable for routine clinical use in orthodontics. Dual- or tri-cured hybrid materials, however, comprising both glass ionomer and resin components, appear to have greater potential with regard to clinical performance.

A Marcusson, L-I Norevall and M Persson[100] **(1997)** studied the benefit from using glass ionomer cement (GIC) instead of a conventional diacrylate in bracket bonding for the prevention of white spot formation. No additional fluoride treatment other than fluoride toothpaste was prescribed. It is concluded that the use of GIC for orthodontic bonding will result in a significant reduction in the number of white spot surfaces at debonding compared with the use of conventional diacrylate

Vittori Cacciafesta et al[165] **(1998),** evaluated the shear bond strength of Fuji ortho LC, a light cured resin modified glass ionomer, used for direct bonding of stainless steel and ceramic brackets under 4 different enamel conditions: their results indicated that shear bond strength of Fuji ortho LC is significantly enhanced by contaminating the enamel surface with either saliva or water after conditioning, depending on bracket type used. Even water contamination of non conditioned enamel surfaces offer clinically acceptable bond strengths for both stainless steel and ceramic brackets, allowing a safe debonding without enamel damage.

T. J. Gillgrass, P.C.M. Benington, D.T. Millett[24] **(2001)** Compared the time to first failure, the position of band failure at deband, and the change in enamel white spot lesions of teeth bonded with a modified composite or a conventional glass ionomer(Band-Lok,Ketac-Cem.) in a randomized half mouth trial over the full course of orthodontic treatment.The results revealed that overall band failure rates of 5% and 2.8% were recorded for the modified composite and the conventional glass ionomer, respectively, with no significant difference found between their times to first band failure. At the end- of-treatment deband, the position of band failure was predominantly at the enamel-cement interface for the modified composite and at the band-cement interface for the conventional glass ionomer (P <.001). A comparison of changes in mean enamel white spot lesion scores during treatment did not reveal significant differences between the cements.

Akira Komori,Iori Kojima[2]**(2003)** Studied the fluoride release and uptake characteristics of Fuji Ortho Band Paste Pak (GC Corporation, Tokyo, Japan), with that of 3 others commonly used to cement orthodontic bands: a conventional resin-reinforced glass ionomer cement, a polyacid-modified composite resin, and a conventional glass ionomer cement. Results proved that the fluoride uptake and release values of Fuji Ortho Band Paste Pak the new 2-paste resin-reinforced glass ionomer cement were statistically significantly higher than those of the conventional resin-reinforced glass ionomer cement or the conventional glass ionomer cement. The new 2-paste resin-reinforced glass ionomer cement might be a good alternative to conventional products for cementation of orthodontic bands.

Roberto Justus et al[142] **(2010)** stated that by eliminating the organic substances from the enamel surface before etching (deproteinization), orthodontic bond strength can theoretically be increased because the resulting etch-pattern is predominantly type 1 and 2, instead of type 3. The objective of this study was to determine whether deproteinization of human dental enamel surfaces, with 5.25% sodium hypochlorite (NaOCl) before etching, increases orthodontic bracket shear bond strength (SBS) of 2 adhesive systems: a composite resin and a RMGI. It was concluded from this in vitro study that with NaOCl use, bracket bond strength with Fuji Ortho LC is similar to Transbond XT, so that fluoride-releasing RMGIs may possibly be used to bond brackets to reduce the incidence of white spot lesions.

STUDIES ON HYDROPHILIC PRIMERS

Miura et al[111] (1971) described an acrylic resin (orthomite) with linear polymerization using a modified tri-alkyl borane catalyst that proved to be particularly successful for bonding plastic brackets and for enhanced adhesion in presence of moisture.

Robert J. Feigal, et al[141] (1992) investigated bond strength in vitro, using a bonding agent beneath sealants under varied conditions of contamination. Five hundred bovine incisor crowns were separated randomly into eight groups and etched for 60 sec with a 37% phosphoric acid gel under conditions of humidity of intact saliva, sealant alone showed significant reduction in bond strength. Bonding agent under sealant on wet contamination yielded bond strengths equivalent to the bond strength obtained when sealant was bonded directly to clean, etched enamel. They concluded that bonding agent used without contamination yielded bond strengths significantly greater than the bond strength obtained when using sealant alone with contamination. When the saliva was air dried onto the surface, there was no significant difference in bond strengths whether or not a bonding agent was used under the sealant.

J. Xie et all[174] (1993) studied the in vitro bond strength of human enamel and dentin treated with contaminants like air, water , saliva , plasma and hand piece lubricant. Two commercial bonding agents, a lower viscosity solvent containing type - All bond and a higher viscosity hydrophilic monomer type Scotchbond were evaluated. They concluded that bond strengths to tooth structure with the bonding agents tested may be less sensitive to common forms of contamination than typically assumed. Re- etching without additional mechanical preparation is sufficient to provide the expected bond strength.

Vargas et al[162] (1994) investigated the use of dentin bonding agents containing hydrophilic primers on enamel. Using HEMA (hydroxyl-ethyl methacrylate) base “scotchbond multipurpose”, equivalent bond strengths to enamel were achieved in dry or moist conditions.

Andrew L. Sonis[7] (1994), did an in vitro test to compare the shear bond strength of **“**scotchbond multipurpose” primer in saliva contaminated enamel surface with conventional primer in uncontaminated enamel and found that the bond strength were similar.

Wakefield C. W.[166] (1996) determined the effect of oral ambient air on shear strength to etched enamel and dentin using OptiBond FL and Prodigy resin composite. Enamel and dentin specimens of extracted human teeth were treated both in a dry environment and after exposure to oral humidity. Differences in shear strengths between the wet and dry enamel or the wet and dry dentin were not significant. Fracture modes for all specimens were examined under a stereomicroscope. Within the parameters of this in vitro study, OptiBond FL was not affected by oral humidity.

El- Kalla[51] (1997) compared the shear bond strengths of 4 single- bottle adhesives to enamel and dentin contaminated with human saliva. Materials used were Prime and Bond 2.1, One Step, Tenure Quick and Syntac single component systems. The results showed that the saliva contamination of enamel or dentin did not affect the shear bond strength of the adhesives tested except for Syntac Sc with contaminated dried enamel. Prime and Bond 2.1 showed significantly higher bond strengths to enamel than the other adhesives, but there was no significant difference for dentin bond strength under the contaminated condition.

Fritz U. B., J Finger W. J., Stean. [63] **(1998)** determine the effect of salivary contamination of enamel and dentin on bonding efficacy of an experimental one- bottle resin adhesive. The control group used was a light- curing urethane dimethacrylate adhesive. The results showed that there was no negative effect in Group 3 and 4, compared with control. Air drying after salivary contamination in Group 2 resulted in lower shear bond strength and wide marginal gaps. Contamination of the cured adhesive layer group 5 and 6 had no adverse effect on enamel shear bond strengths, they conclude that the one- bottle adhesive system is relatively insensitive to salivary contamination, provide that the contamination occurs prior to the light curing of the adhesive and is carefully rinsed and blot dried. Salivary contact after adhesive curing must be avoided.

Iwami . Y[84] **(1998)** evaluated the effect of the wetness of human enamel and dentin surfaces on the shear bond strength of composites. Seven dentin bonding system were used. Shear bond strength was measured with a universal testing machine. Among the dentin specimens which were tested by two systems with water based primers, the shear bond strength values of the dry technique group were higher. Among the acetone based primers the bond strength values for the wet or semi dry technique groups were higher than those of the dry technique group. It was concluded that some water might be needed by dentin surfaces or for the primers to obtain high bond strength on the dentin surfaces, but the drying methods did not affect bond strength to enamel surfaces either before priming or after conditioning.

Miller[106] (1998) discussed wet field bonding in the 21st century. He compared the shear bond strength of Transbond XT primer and Transbond MIP on wet and dry etched enamel. In the dry state, both primers showed comparable bond strengths; however, under wet conditions, Transbond MIP was vastly superior.

Samir E. Bishara[146] (1998), did a study on a RMGIC (Fuji Ortho LC). He studied the bond strength on various enamel conditions viz: etched and unetched surfaces both moistened with saliva and water. He concluded that etching is a critical variable affecting both the bond strength and the failure location and it improved the bond strength. With unetched enamel, the shear bond strength of RMGIC is significantly reduced by a third to a half to that of etched enamel.

Benderli Y[15], (1999) examined the shear bond strength of bonding agents to normal or fluoridated enamel following use of weak or strong acids to prepared enamel surfaces and contaminated with a measured amount of saliva at various stages of the bonding procedure . When normal enamel surfaces were rinsed and dried immediately after contamination, there was no significant reduction of shear bond strength of adhesive to enamel. In the fluoridated specimens, there was no statistically significant difference between any of the contamination groups and the control group when maleic acid was used. Saliva contamination may not be a risk factor for successful bonding between bonding agent and dental tissues for normal or fluoridated enamel surfaces if they are rinsed and dried immediately after contamination. Etching of normal enamel surfaces with phosphoric acid in the presence of contamination may provide higher shear bond strength than etching with maleic acid.

Swift. J. Jr.[157] **(1999)** evaluated bond strengths of six one-bottle bonding agents and a control primer, plus unfilled resin to moist enamel. One-hundred and five bovine teeth were randomly assigned to seven groups of 15. Enamel was etched for seconds with 35% phosphoric acid, rinsed, and excess water was blotted with tissue paper. Following application of the adhesive, composite resin was bonded using a gelatin capsule technique. Shear bond strengths to enamel were determined using a universal testing machine. The results of this study suggested that all of the one-bottle systems tested provided clinically acceptable bond strengths to moist enamel.

W. Pitakononda[173] **(1999)** evaluated the shear bond strength of three orthodontic bonding agents namely, Concise, Chemical Cure, Rely-a-Bond and Transbond XT. Ortho-sealant in conjunction with bonding agents resulted in increased bond strength after moisture exposure for a prescribed period It was concluded that the time differences of moisture exposure did not have a significant effect on the shear bond strength of the three commercial brands of bonding agents, and both Concise and Transbond XT had shear bond strengths statistically significantly greater than Rely-a-Bond, and the use of Ortho-sealant purported to prevent moisture interference during polymerization and when it was applied around the border of bracket after bonding procedure, did not have a significant effect.

Takami Itoh et al[159] **(1999),** studied the effect of water and saliva contamination on the bond strength of metal orthodontic brackets cemented to etched (10% polyacrylic acid) and unetched human premolar enamel . Two products: one commercially available product (Fuji Ortho LC) and one experimental (EX) light-cured glass ionomer. Bond strength was measured after aging for 5 minutes, 15 minutes, and 24 hours. For Fuji Ortho LC, the bond strength of brackets bonded to, etched and without contamination, was statistically higher than that of brackets bonded to unetched enamel for all aging times. Contamination by saliva did not reduced bond strength to unetched enamel. For both etched and unetched enamel, there was no significant difference between Fuji Ortho LG and EX after 24 hours for all contamination conditions.

Hara.AT[71] (1999) compared the enamel shear bond strength of four hydrophilic adhesive systems: one multiple-bottle (Scotchbond Multi-Purpose Plus), two one-bottle (Stae, Single Bond) and one self-etching (Etch & Prime) after storing in humid environment for 1 week. The mean shear bond strength values were: Single Bond: 24.28 +/- 5.27 (a); Scotchbond Multi-Purpose Plus: 21.18 +/- 4.35 (ab); Stae: 19.56 +/- 4.71 (b); Etch & Prime 3.0: 15.13 +/- 4.92 (c). It could be concluded that the self-etching adhesive system did not provide as good a bond to enamel surface, as did the one- and multiple-bottle systems.

Cacciafesta V, Bosch C, Melsen B[31]. (1999), compared the clinical performance of resin-modified self-cured glass ionomer cement to a standard composite resin in the direct bonding of orthodontic brackets when bonded onto dry and saliva contaminated enamel. After bond strength testing, they concluded that, GC Fuji Ortho shows clinically acceptable bond strength when bonded onto moist teeth, but not when used on dry enamel. Both bonding agents failed mostly at the enamel-adhesive interface, without causing any enamel damage.

Littlewood et al[96] (2000), carried out a study to investigate the bond strength of brackets bonded using a new hydrophilic primer designed to be insensitive to moisture and compares it with a conventional primer. Although designed to be moisture insensitive, the directions for use stipulate drying teeth before bonding. Therefore, for the purpose of comparison with a conventional primer, the experiment was conducted under dry conditions. The results showed that the bond strengths obtained with a hydrophilic primer were significantly lower than the conventional primer.

I.Kirovshi and S. Madzarova[79] (2000), investigated the effects of etching and 3 different environmental conditions (Distill water, saliva and plasma) on the bond strength of a light-cured RMGIC (Fuji Ortho LC). The results showed that etching of enamel produced higher bond strengths when compared to non-etched surfaces and also, the contamination with saliva or plasma increased the bond strength. The material provided adequate bond strengths for direct bonding.

Hobson et al[77] (2001), did an in-vitro study to evaluate the bond strength of Transbond MIP under dry, moist and blood contaminated conditions. The results showed higher bond strength in dry followed by moist and blood contaminated surfaces respectively. It was concluded that bonding with Transbond MIP even under the difficult conditions of blood contamination and poor moisture control provides more than adequate bond strength.

Mark J. Webster, Nanda[101] (2001) did an in-vitro study to compare the shear bond strengths of two light-cured hydrophilic bonding systems, namely Transbond XT with MIP and Assure (Reliance orthodontics Itasca, III) with a hydrophobic bonding system Transbond XT with XT primer.Comparison tests were conducted under four enamel surface conditions: Etched and dry, Etched and moisture with artificial saliva, Etched, primer and moistened with artificial saliva and Etched, primed, moistened with artificial saliva and reprimed.

After doing the bond strength tests, they concluded that the enamel etched and dried and enamel etched, primed, moistened with saliva and reprimed (i.e. a and d) showed highest mean bond strength.

Littlewood et al[96] (2000) did a clinical study to compare the clinical failure rates of brackets bonded using a prototype hydrophilic primer designed to be insensitive to moisture with brackets bonded with a conventional primer. He concluded using survival analysis that there was an increased risk of bracket failure when bonded with the hydrophilic primer compared with the conventional primer therefore this hydrophilic primer cannot be recommended for routine clinical use.

Douglas Rix et al[45] (2001), compared 3 orthodontic adhesives in the areas of shear-peal bond strength, location of adhesive failure, and extent of enamel cracking before bonding after debonding of orthodontic brackets. The adhesives included were composite resin control, Fuji Ortho LC and a polyacid modified composite resin (Assure) under dry and saliva contaminated conditions. They concluded that, Transbond XT had higher bond strength than Fuji Ortho LC and Assure (polyacid composite), although the bond strength for all 3 adhesives were clinically acceptable. The bond strength for the Assure adhesive was not significantly affected by saliva contamination.

Grandhi et al[67] **(2001)** did an in-vitro study on bovine enamel to evaluate the shear bond strength of stainless steel brackets bonded in dry and wet field with the use of MIP and to evaluate the effectiveness of MIP with chemically activated (concise) and light activated (Transbond XT) composite resin.The results of this study suggested that MIP should be used with only (Transbond XT) light-cured resins as this combination produced higher bond strength and suggested the use of MIP in situations where moisture control is difficult.

Eliades et al[50] **(2002),** did a study to investigate the reactivity with water of Transbond MIP in conjunction with a no-mix adhesive (Unite), and a moisture insensitive adhesive (Smartbond), and to assess their bond strength to wet and saliva contaminated enamel relative to the conventional application of the no-mix adhesive.After the bond strength testing, they concluded that only Smartbond set in the presence of water. Transbond MIP did not improve bond strength values when combined with the no-mix adhesive. Most adhesive-enamel condition combinations showed a trend to present lower bond strength in the presence of saliva; however, this was not confirmed statistically.

Moll K., Gartner, Haller B.[113] **(2002),** evaluated the effect of moist bonding on strength of resin based composite to enamel using different adhesive systems: They concluded that moist bonding did not significantly affect shear bond strength to enamel of the adhesives tested expect for solid bond without primer application. Primer contamination of the etched enamel did not significantly influence bond strength, neither in the dry nor in the moist bonding group. Of all 6 adhesives tested in the both group, the highest mean bond strength was observed with prime and bond 2.1 and the lowest with Etch and Prime 3.0

Shane Schaneveldt and Foley[149] (2002), did an in vitro bonding study to evaluate the effectiveness of 2 moisture insensitive primers, Assure and MIP compared with a control hydrophobic primer, Transbond XT.

After bond strength testing, they concluded that:-

1. Both bonding systems provide adequate bond strengths whether saliva contamination occurs before or after the application of the hydrophilic primers.
2. Comparing saliva contamination after application of primer, both MIP and Assure had significantly greater shear-peel bond strengths than when contamination occurred before the application of each primer.
3. Contamination between 2 layers of primer showed significantly greater shear-peel bond strengths compared with the other groups.
4. The group with saliva contamination before application of the primer showed more frequent failure at the enamel-adhesive interface, suggesting that complete penetration of primer was prevented. Whereas the groups with saliva contamination after the first application of primer showed more frequent failures at the adhesive-bracket interface.

Cacciafesta et al[32] (2003), did a study to assess the effect of water and saliva contamination on the shear bond strength and bond failure site of 3 different orthodontic primers (Transbond XT, Transbond MIP. And Transbond plus Self

Etching Primer) used with a light-cured composite resin (Transbond XT).Comparison test were conducted under 7 different enamel surface .After bond strength testing, they concluded that non-contaminated enamel surfaces had the highest bond strengths for conventional, hydrophilic and Self etching Primers, which produced the same strength values. In most contaminated conditions, the Self Etching Primer had higher strength values than either the hydrophilic or conventional primers. The Self Etching Primer was the least influenced by water and saliva contamination, except when moistening occurred after the recommended 3-second air burst.

Kula KS., Nash TD., Purk JH[93].(2003), determined whether a hydrophilic primer (Transbond MIP) produced a significant difference in shear/peel bond strength compared with a traditional hydrophobic primer (Transbond XT) in wet and dry condition and difference in site of bond failure.

They concluded that orthodontists who suspect moisture contamination should use a hydrophilic primer during bonding procedures to maintain shear/peel bond strength.

Ashraf E. Nasr[11] (2003) evaluated the effectiveness of moisture-insensitive primers and hydrophilic adhesive under dry, moisture contamination and saliva contamination. One commercially available micro- hybrid composite resin and compomer dental restorative materials both are light cured and with their corresponding etching primer and adhesives. The results indicated that moisture contamination either with saliva or distilled water decrease the shear bond strength even for moisture insensitive primers and adhesives. But polyacid modified composites, compomers are less sensitive to moisture contamination than resin composites. This decreased sensitivity mechanism was unclear, while hygroscopic expansion is suggested to play role, This hygroscopic expansion is high in Dyract Ap due to the predominance of (poly hydroxyethyl methacrylate) that act as water binding hydrogel.

Vittoria cacciafesta[164] (2004), studied regarding effect of blood contamination on the shear bond strength of conventional and hydrophilic primer.

1. Non contaminated enamel surface had the highest bond strength for both conventional and hydrophilic primer.

2. Under blood contamination, both primers produces significantly lower bond strengths. The hydrophilic primer had significantly higher bond strength values than the conventional primer, but they both had bond strength values that might not be clinically adequate.

3. Both shows significant debond failure site, depending on enamel surface conditions.

Rangaswamy Rajagopal et al[135] (2004) Shear bond strength was compared among three materials: conventional Transbond XT primer (3M Unitek), moisture-insensitive primer (MIP, 3M Unitek), and self-etch primer (Transbond plus, 3M Unitek). Both MIP and self-etch primer showed adequate bond strength superior to that of conventional primer in case of moisture contamination. All primers showed typical debonding characteristics of separation at the bracket-adhesive interface or within the adhesive itself, with the exception of the conventional primer used with moisture -contaminated enamel.

Ciola[36] (2006) investigated, in vivo, the bond strength of two adhesive materials: a moisture insensitive primer (MIP) and a one step self etching primer (SEP), both used with Transbond XT on dry and wet enamel and an adhesion time of 10-15 minutes.Moisture insensitive primer tested on wet enamel showed the highest mean bond strength outcomes (8.98 MPa) compared to one step etching primer (5.81 MPa). Since the mean bond strength of SEP proved sufficient for clinical purposes and its behavior tended to be more homogeneous, it was considered the best choice.

Mehmet Og˘ uz Öztoprak[105] **(2007)** assessed the effect of blood and saliva contamination on the shear bond strength of 4 orthodontic adhesives (Transbond XT primer ,Transbond Plus self-etch primer , Assure hydrophilic primer and Smartbond cyanoacrylate)tested under different enamel conditions: dry, and blood and saliva contamination after priming. Result showed that the shear bond strength of the Smartbond cyanoacrylate adhesive group was significantly lower than all other groups; however, it was the only adhesive that was not affected by contamination. Saliva and blood contamination resulted in significant drops in shear bond strengths of the Transbond XT and Assure groups. Transbond Plus self-etch primer was also negatively affected by blood contamination, although it was suitable for bonding with saliva contamination.

Endo T[52](2008) evaluated the effects of different degrees of water contamination on the shear bond strength of orthodontic brackets bonded to dental enamel with a moisture-insensitive primer (MIP) adhesive system and to compare the modes of bracket/adhesive failure. They concluded that to achieve clinically sufficient bond strengths with the hydrophilic MIP adhesive system, excess water should be blotted from the water-contaminated enamel surface.

Luciana Borges Retamoso et al[97] (2009) evaluated the influence of saliva contamination on shear bond strength and the bond failure pattern of 3 adhesive systems (Transbond XT, AdheSE and Xeno III) on orthodontic metallic brackets bonded to human enamel after storing in distilled water at 37ºC for 24 hour. Each system was tested under 2 different enamel conditions: no contamination (T, A and X groups) and contaminated with saliva (TS, AS and XS groups). They concluded that the control and contaminated groups showed no significant difference in shear bond strength for the same adhesive system. However, shear bond strength of T group was significantly higher than that of AS and XS groups.

Santos et al[147] (2010) compared the shear bond strength (SBS) of two bond systems: Transbond XT/XT primer (TXT/XT) and Transbond Plus Color Change/Transbond Self Etching Primer (TPCC/TSEP)after thermocycling. Each system was examined under four enamel surface conditions (dry, water, saliva, and blood), and 160 bovine teeth were divided into eight groups of 20 according to enamel surface condition. Group 1 used TPCC/TSEP and Group 2 used TXT/XT under dry conditions; Group 3 used TPCC/TSEP and Group 4 used TXT/XT with water; Group 5 used TPCC/TSEP and Group 6 used TXT/XT under saliva; and Group 7 used TPCC/TSEP and Group 8 used TXT/XT with blood. They concluded that the presence of blood resulted in the lowest SBS from both bond systems, but especially from TXT/XT. TPCC/TSEP resulted in a higher SBS than TXT/XT under all conditions except the dry enamel surface.

STUDIES ON THERMOCYCLING

Bishara et al[19] (1975) Plastic brackets were bonded to 560 extracted human teeth with use of two orthodontic adhesive systems: (1) methyl methacrylate resin bonded to a sealant that was polymerized using ultraviolet light, and (2) self-polymerizing methyl methacrylate resin bonded directly to the etched enamel. Tensile and shear like tests were performed. Prolonged exposure to heat, moisture, and severe temperature changes decreased the shear like strength of both adhesives. Both systems were adequately strong to withstand routine orthodontic and estimated masticatory forces.

Schaneveldt et al[144] (2002) evaluated the effectiveness of 2 moisture-insensitive primers, Assure and MIP compared with a control hydrophobic primer, Transbond XT . In vitro shear-peel bond strengths were acceptable for all groups, and the bond strengths for Assure and MIP were not significantly affected by saliva contamination. Bond failure analysis (adhesive remnant index) mainly showed adhesive bond failures. An increased frequency of enamel fractures at debond was noted, with the control group (1) and the MIP groups (3 and 5) having 22.5%, 12.5%, and 15%, respectively. The Assure groups had no enamel fractures.

Bishara et al[21] (2003) evaluated the effects of thermocycling on the shear bond strength of a cyanoacrylate adhesive system, specifically 24 hours after bonding when the adhesive has achieved most of its bond strength and after thermocycling. The findings indicated that the cyanoacrylate adhesive tested has clinically adequate shear bond strength at 24 hours after initial bonding but loses about 80% of its strength after thermocycling. The clinician should consider all properties of the adhesive, including no need for a curing light, working time of 5 seconds before the adhesive starts to set, and the significant decrease in bond strength after thermocycling.

De Munck et al[42] (2005) in their review of literature, concluded that after about 3 months, all classes of adhesives exhibited mechanical and morphological evidence of degradation that resembles *in vivo* aging effects. A comparison of contemporary adhesives revealed that the three-step etch-and-rinse adhesives remain the 'gold standard' in terms of durability. Any kind of simplification in the clinical application procedure results in loss of bonding effectiveness. Only the two-step self-etch adhesives approach the gold standard and do have some additional clinical benefits.

J. De Muncket al[86] (2005) reviewed the fundamental processes that cause the adhesion of biomaterials to enamel and dentin to degrade with time. Several laboratory protocols were developed to predict bond durability. A correlation of in vitro and in vivo data revealed that, currently, the most validated method to assess adhesion durability involves aging of microspecimens of biomaterials bonded to either enamel or dentin. Various methods by which aging achieved are,

1. Aging by storage
2. Aging by thermo-cycling
3. Aging by occlusal loading
4. Combination of all

After about 3 months, all classes of adhesives exhibited mechanical and morphological evidence of degradation that resembles in vivo aging effects. A comparison of contemporary adhesives revealed that the three-step etch-and-rinse adhesives remain the 'gold standard' in terms of durability. Any kind of simplification in the clinical application procedure results in loss of bonding effectiveness. Only the two-step self-etch adhesives approach the gold standard and do have some additional clinical benefits.

Andreas Faltermeier et al[6] (2007) evaluated the shear bond strength of a conventional primer (Transbond XT) and a moisture-insensitive primer (Transbond MIP) under dry conditions and after contamination with saliva, blood and etching gel remnants after thermocycling(6000× 5°C/55°C) in a mastication device to simulate temperature changes and the moisture of saliva in the oral cavity. Under dry conditions Transbond XT and Transbond MIP showed no significant difference in SBS. However, clinically unacceptable bond strength was observed using Transbond XT after saliva and blood contamination. In wet conditions only Transbond MIP showed sufficient bond strength. Blood contamination seems to be a more serious problem for bond strength than saliva or etching gel contamination.

Oesterle LJ, Shellhart WC (2008) did evaluate and isolate the effect of composite aging, one of many factors that can contribute to decreased bond strength during a normal 24-month orthodontic treatment period. Two orthodontic bonding adhesives--Transbond APC II and Quick Cure adhesive were used to bond brackets to 280 bovine incisors that were stored in distilled water at 37 degrees C for 30 minutes, 24 hours, and 1, 6, 12, 18, and 24 months before shear-peel testing. They concluded that the shear bond strength of orthodontic brackets increases from 30 minutes to 24 hours and then tends to decrease over the next 24 months. The decrease in bond strength due to the effects of composite aging in water appears to be a major factor in the decreased bond strength seen clinically.

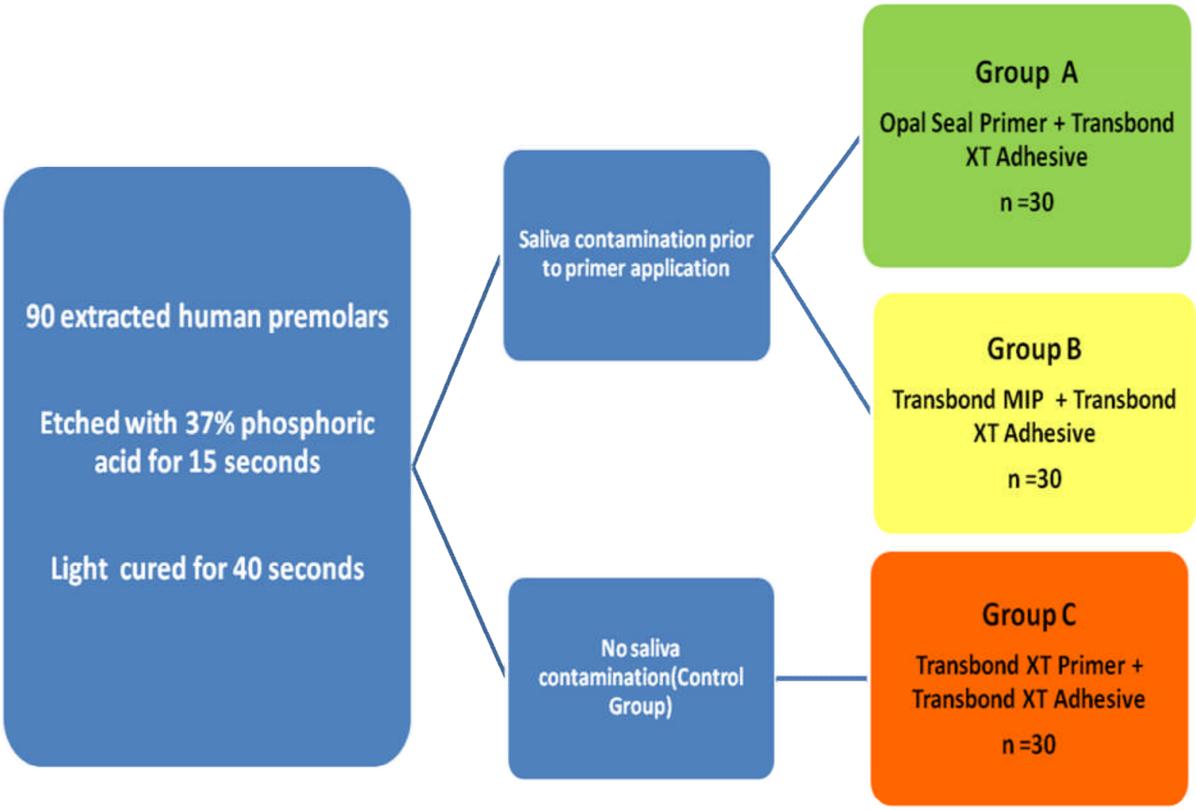
Chatzistavrou E et al[35] **(2009)** assessed the effect of intra-oral aging on the shear bond strength of a composite resin orthodontic adhesive (Transbond XT, 3M Unitek, Monrovia, CA, USA) after 6 months in the oral cavity and to compare it with control specimens not subjected to intra-oral aging. No statistically significant differences were found in the shear bond strength between the two groups of composite resin adhesive systems (with and without clinical aging) or in the adhesive remnant coverage following debonding. No significant correlation was detected between the shear bond strength and the adhesive remnant coverage in the test specimens with and without aging. Laboratory studies of shear bond strength appear to be clinically relevant.

Toshihiro Yuasa[156] **(2010)** evaluated the effects of 2 years of storage and 6000 thermocycles on the shear bond strength (SBS) of two self-etching adhesive systems were studied. Two self-etching primer (SEP) systems (Transbond Plus and Beauty Ortho Bond) and one etch and rinse system (Transbond XT) were used . There was no significant difference in the mean SBS for the bonding materials among the three conditions. ARI scores showed that Transbond XT and Beauty Ortho Bond had less adhesive remaining on the teeth after ageing compared with storage for 24 hours. Specimens bonded with Beauty Ortho Bond showed leakage between the resin adhesive and enamel after ageing. Both SEP systems produced adequate SBS even after 2 years or 6000 times thermocycling. Thermocycling is an appropriate technique for determining the durability of orthodontic bracket bonding materials.

Oral Sökücü et al[127]**(2010)** compared the effect of thermocycling on the shear bond strength of brackets bonded using different primers. In all three, Transbond XT was the bonding adhesive of choice. In the control group (I), the standard Transbond primer was used, in group II a fluoride-releasing primer (Reliance fluoride containing light cure bond), and in group III an antimicrobial fluoride-releasing self-etching primer (Clearfil Protect Bond). The shear bond strength was determined after thermocycling .They concluded that The group with the antimicrobial fluoride-releasing self-etching primer had a significantly lower shear bond strength than all other groups ($P < .05$). Thermocycling reduced the shear bond strength in all groups considerably.

Materials and Methods

CONSORT DIAGRAM



MATERIALS AND METHODS

The various material, apparatus and the methodology used in the study are enumerated and briefly described below.

MATERIALS

1. TEETH USED FOR THIS STUDY :

a. **90** sound human adolescent premolars extracted for orthodontic purpose were collected immediately after extraction.

b. The teeth were cleaned of soft tissue debris and blood and washed with distilled water thoroughly and stored in 10% formalin.

Inclusion Criteria

- ❖ Intact buccal enamel
- ❖ No evidence of caries
- ❖ No development defects
- ❖ No cracks due to the pressure of the extraction forceps.
- ❖ Teeth without any restorations
- ❖ Absence of pre-treatment with chemical agents (such as hydrogen peroxide).

2. **BRACKETS**

a. Stainless steel pre-adjusted edgewise, ROTH 0.022 slot premolar brackets with metallic foil-mesh backing (diamond, Mini 2000 series, Ormco) were used.

b. The average bracket base surface area was determined to be 9.63 mm^2 (given by manufacturers and also tested).

2. **ETCHANT**

37% orthophosphoric acid

3. **PRIMERS**

a. Opal seal – primer containing fluoride releasing and recharging with drying agent (Opal Ultradent ,Texas)

b. Transbond moisture insensitive primer. (Transbond MIP, 3M Unitek, Monrovia, California).

c. Transbond XT primer(3M Unitek, Monrovia, California)

4. **ADHESIVES**

Transbond XT (3M Unitek, Monrovia, Calif).

5. **LIGHT CURE KIT**

3M Unitek halogen curing light, visible light range - 400 to 500 nm, Light power - 450mw/cm².

6. **DPI RR COLD CURE ACRYLIC**, DPI Wallace Street, Bombay.

7. **OTHER MATERIALS AND ARMAMENTARIUM INCLUDED:**

- ❖ Moulds for making acrylic blocks into which teeth were fixed.
- ❖ Distilled water, polishing cup and slurry of pumice.
- ❖ Bracket positioner, Tweezer & Explorer.
- ❖ Plastic instrument and spatulas.
- ❖ Compressed air / water facility with a 3-way syringe.
- ❖ Dental micromotor unit with hand piece.
- ❖ Mixing well.
- ❖ Saliva: artificial saliva-made with international standards that contains both organic and inorganic components

8. **THERMOCYLER**

Willitech thermocyler with cooling system, Haake EK 30, Thermoelectron Corporation, Germany

9. **UNIVERSAL TESTING MACHINE**

Universal testing machine (INSTRON 3365, UK) was used for measuring mean shear bond strength.

METHODOLOGY

- 90 human adolescent premolars extracted for orthodontic purpose were collected over a 3-month period.
- The teeth were debrided and examined for caries, pre-existing fractures, and restorations.
- The criteria included intact buccal and lingual enamel surface with no cracks caused by pressure of the extraction forceps.
- The teeth were stored in 10% formalin initially and cleaned and stored in distilled water 48hrs prior to the experiment.

SAMPLE PREPARATION

- 90 premolar teeth were randomly assigned to 3 groups with 30 teeth per group.
- Each group was given different colour coding
    1. Green – for Opal seal (Group A)
    2. Yellow- for Transbond MIP (Group B)
    3. Orange- for Transbond XT (Group C)
- Each tooth from the in vitro sample was mounted on acrylic stubs with roots embedded in a fast set self cure polymethylmethacrylate resin.
- The teeth were oriented such as to ensure that the height of contour of the buccal surfaces were perpendicular to the adhesive and bracket base.

BONDING PROCEDURE

Brackets were bonded to the teeth according to the instructions given by the manufacturer. All the bonding procedures were carried out by the same operator.

GROUP A (Green- Opal seal)

1. Teeth were pumiced with non-fluoridated pumice, rinsed thoroughly with water spray and dried.

2. Enamel surface of the teeth were etched with 37% phosphoric acid for 15 seconds, and then rinsed with water spray for 10 seconds and gently air dried.

3. The buccal surfaces were coated with thin layer of artificial saliva.

4. Opal seal- one liberal coat was applied on the entire buccal etched surface avoiding the gingival area. Then it was air bursted gently for 3 seconds perpendicular to the buccal surface.

5. The brackets (Roth 0.22 slot premolar, diamond, miniseries 2000 Ormco) were coated with Transbond XT resin, and placed on the buccal surface of the tooth and pressed firmly into place to expel the excessive adhesive.

6. The excess adhesive was removed with a scaler. The resin was cured for a period of 40 seconds, 10 seconds proximally, 10 seconds occlusally and 10 seconds gingivally.

GROUP B (Yellow- Transbond MIP)

1. Teeth were pumiced with non-fluoridated pumice, rinsed thoroughly with water spray and dried.

2. Enamel surface of the teeth were etched with 37% phosphoric acid for 15 seconds, and then rinsed with water spray for 10 seconds and gently air dried.

3. The buccal surfaces were coated with thin layer of artificial saliva.

4. Transbond MIP - one liberal coat was applied on the entire buccal etched surface avoiding the gingival area. Then it was air bursted gently for 3 seconds perpendicular to the buccal surface.

5. The brackets (ROTH 0.22 slot premolar, diamond, miniseries 2000 Ormco) were coated with Transbond XT resin, and placed on the buccal surface of the tooth and pressed firmly into place to expel the excessive adhesive.

6. The excess adhesive was removed with a scaler. The resin was cured for a period of 40 seconds, 10 seconds proximally, 10 seconds occlusally and 10 seconds gingivally.

GROUP C (Orange - Transbond XT)

1. Teeth were pumiced with non-fluoridated pumice, rinsed thoroughly with water spray and dried.

2. Enamel surface of the teeth were etched with 37% phosphoric acid for 15 seconds and then rinsed with water spray for 10 seconds and gently air dried.

3. A thin layer of Transbond XT primer was applied on the buccal surface of teeth.

4. The brackets (ROTH 0.22 slot premolar, diamond, miniseries 2000 Ormco) were coated with Transbond XT resin, and placed on the buccal surface of the tooth and pressed firmly into place to expel the excessive adhesive.

5. The excess adhesive was removed with a scaler. The resin was cured for a period of 40 seconds, 10 seconds proximally, 10 seconds occlusally and 10 seconds gingivally.

After bonding all the samples were stored in distilled water in sealed container at room temperature for 48 hrs. The specimens were thermocycled (500 x) between 5ºC and 55ºC, (Haake EK 30, Thermoelectron corporation, Germany) with a dwell time in each bath of 30 seconds and a transfer time between baths of 15 seconds. Twenty four hours after thermocycling, they were subjected to a shear load test in a Universal Testing Machine for Shear bond strength (SBS).

The specimens were placed in a mounting jig in the INSTRON universal machine (INSTRON 3365, UK) in such a way that the bracket base was parallel to the shear-peel load. To ensure that all the brackets were mounted in the same orientation relative to the acrylic cylinder, the teeth were suspended from a stainless steel wire (0.019×0.025 inch). This mounting procedure ensured consistency for the point of force application and direction of the debonding force.

A shear debonding force was applied to the bracket base in an occluso-gingival direction at a crosshead speed of 1mm/ min. The maximum force necessary to debond or initiate bracket fracture was recorded in Newtons and then converted into Megapascals (MPa) as a ratio of Newtons to bracket base surface area. Debonded specimens were randomly examined at 16x magnification to evaluate the site of bond failure.

TEST FOR DEBONDING CHARACTERISTICS

The surface of debonded specimens (both the tooth surface and the bracket base surface) were studied under 16 X magnification and the mode of bonding failure was determined using the Adhesive remnant index (ARI) which describes the amount of adhesive remaining on the tooth and bracket pad and was expressed as a percentage of the total bonded area.

Adhesive remnant index developed by **Artun and Bergland** were used in this study to assess each specimen.

The score ranges for ARI are:

Score 0 - no adhesive left on the tooth in the bonded area

Score 1 - less than half of the adhesive left on the tooth

Score 2 - more than half of the adhesive left on the tooth

Score 3 - the entire adhesive left on the tooth with distinct impression of the bracket base.

STATISTICAL ANALYSIS

Statistical analysis was performed with SPSS 15.0 software (SPSS Inc, Chicago). Descriptive statistics of SBS (mean, standard deviation and significance) were calculated for all groups. One-way analysis of variance (ANOVA) and Chisqare test were carried out for SBS and ARI, respectively, to determine significant differences among the groups. The intergroup comparison of SBS was done with Independent T- test. The statistical significance level was established at $P < 0.05$.

ARMAMENTARIUM USED IN THE STUDY

PRIMERS USED IN THE STUDY

3M UNITEK LIGHT CURING UNIT

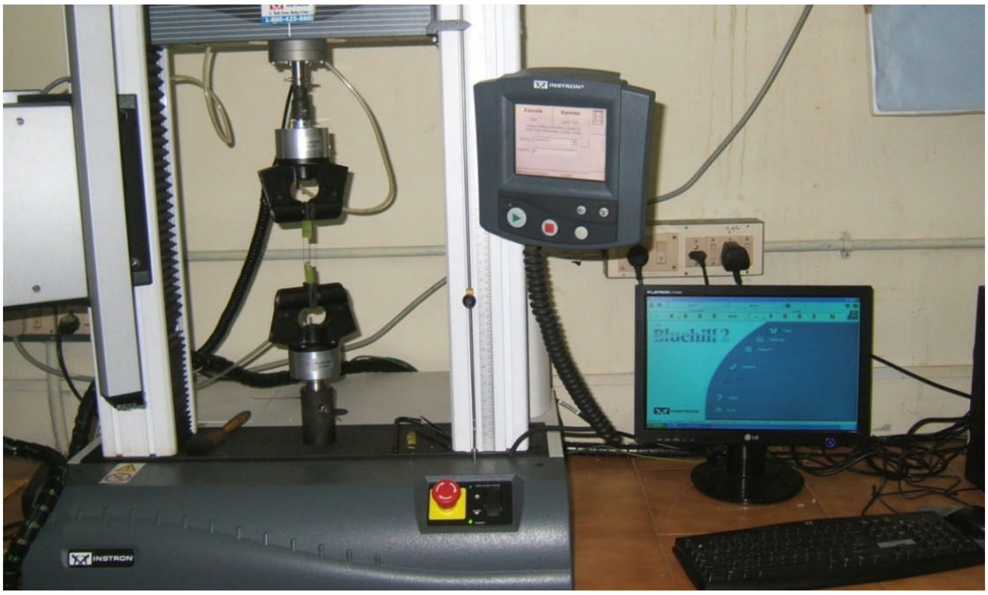
COLOURS TO IDENTIFY GROUPS

SAMPLES MOUNTED IN ACRYLIC BLOCK

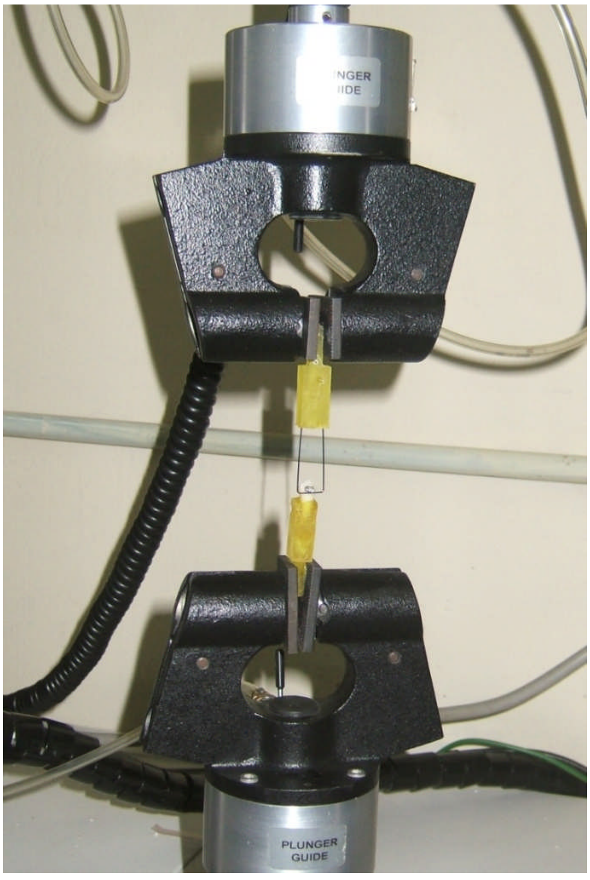
WILLITECH THERMOCYLER

SAMPLES DURING THERMOCYCLING

INSTRON UNIVERSAL TESTING MACHINE



SAMPLE BEING TESTED FOR SHEAR BOND STRENGTH

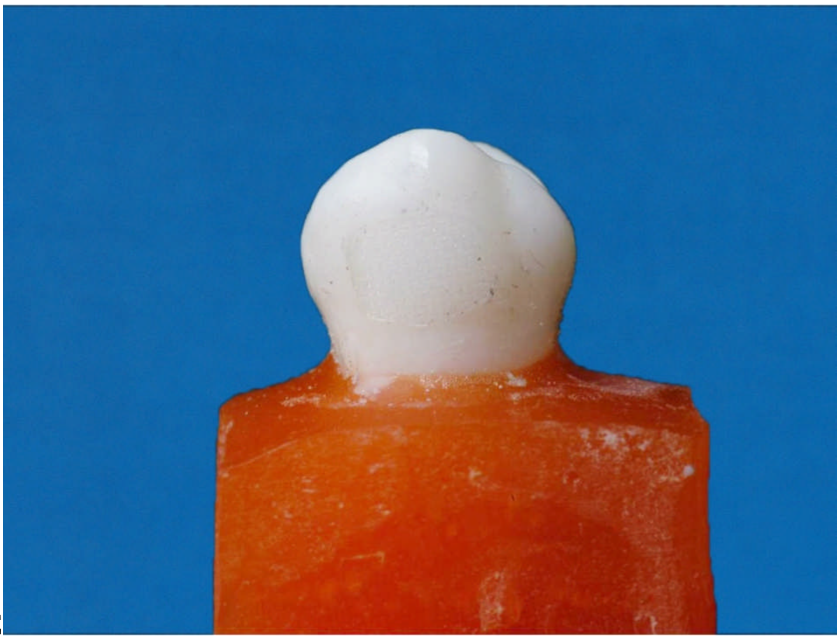


ASSESSMENT OF ARI ON TOOTH SURFACE

OPAL SEAL - GROUP A

TRANSBOND XT- GROUP

C



Results

RESULT

This study was performed on 90 premolars extracted for orthodontic purpose and free of caries, without enamel damage. They were divided into 3 equal group and colour coded.

Group A = Green

Artificial saliva +opal Seal primer + Transbond XT adhesive

Group B = Yellow

Artificial saliva + Tran bond MIP primer + Tran bond XT adhesive

Group C = Orange

Transbond XT primer + Transbond XT adhesive

After bonding all the samples were stored in distilled water in sealed container at room temperature for 48 hrs and then thermocycled (500 x) between 5ºC and 55ºC, with a dwell time in each bath of 30 seconds and a transfer time between baths of 15 seconds in Willitech thermocyler with cooling system, Haake EK 30, Thermoelectron corporation, Germany.

INSTRON universal machine (INSTRON 3365, UK) set at a speed of 1mm/minute was used to evaluate shear bond strength and the readings were expressed in Megapascals (Mpa) as shown in Table 1 and Graph 1 depicts the results in the form of a Bar graph. The bond strength was calculated in megapascals using the formula,

$$\text{Bond strength MPa} = \frac{\text{Force in Newtons}}{\text{Surface area of brackets in mm2}}$$

The surface area of the bracket was 9.63 mm2, as given by the manufacturer. The results obtained have been shown in the table 1. Descriptive statistics means, and standard deviations were calculated for the shear-peel band strength data for each adhesive group (Table 3). A one-way analysis of variance (ANOVA) was performed to test for statistical significance (Table 3, Graph1). Independent sample *t*-test was utilized to determine whether there was a significant difference in SBS between Group A and Group B, Group B and group C, and Group A and group C(Table 4). The chi-square test was used to compare the bond failure mode (ARI scores) between the groups (Table 5, Graph 2). Significance for all statistical tests was predetermined at $P < 0.05$.

STATISTICAL INFERENCE

Shear Bond Strength

The mean SBS for the brackets bonded using the Opal seal was 7.204 ± 2.524 MPa; for Transbond MIP 5.727± 1.754 MPa; and for Transbond Primer 10.225± 2.145 MPa. The results of the one-way analysis of variance ($F = 33.672$) indicated statistically significant differences (**$P < 0.001$**) between the groups (Table 3,Graph 1).

Independent sample *t*-test revealed that there was statistically significant difference in SBS between Opal Seal and Transbond MIP with t- value and p- value being 2.633 ,0.011 respectively(Table 4). Both Opal Seal (**T= -4.995, P < 0.001**) and Transbond MIP (**T= -8.890, P < 0.001**) showed highly significant statistical difference in SBS when compared with the control group (Transbond XT).

Adhesive Remnant Index

The failure modes of the three groups are presented in Table 2. The chi-square comparisons (Table 5, Graph 2) of the ARI scores between the three groups ($\chi^2 = 34.95$) indicated that bracket failure modes were significantly different ($P < 0.001$). In Transbond MIP (Group B) and control (Group C) groups, most of the bond failure was within the adhesive with more adhesive on enamel (score 2), while in the Opal Seal group(Group A) the bond failure was similar with less adhesive on enamel (score 1). The comparisons of the ARI scores between the three groups ($\chi^2 = 34.95$) indicated that bracket failure mode was significantly different ($P < 0.001$) with more adhesive remaining on the teeth bonded with Transbond XT (Table 5).

A closer look at the data indicated that there was a greater incidence of bracket failure towards enamel-adhesive interface with the new Opal Seal Primer, i.e., most of the adhesive remained on the bracket.

Table -1

BOND STRENGTH IN MPa

Sample	Group A	Group B	Group C(control)
1	12.08	7.54	7.35
2	13.71	4.99	10.95
3	4.67	3.96	6.93
4	10.61	5.33	12.87
5	9.32	4.25	10.32
6	12.19	5.72	5.94
7	7.01	5.55	11.72
8	6.01	3.98	9.28
9	7.14	3.76	9.33
10	5.63	4.95	11.31
11	4.78	4.67	12.45
12	4.25	8.33	5.6
13	5.77	4.48	12.65
14	5.67	6.52	9.98
15	8.58	6.55	7.72
16	7.11	3.8	8.15
17	4.22	6.34	8.81
18	7.65	10.11	10.09
19	10.75	10.9	11.35
20	4.77	5.16	14.02
21	7.93	3.77	12.95
22	5.98	7.52	10.48
23	5.12	4.68	10.96
24	5.03	5.87	9.47
25	5.47	5.17	9.24
26	7.73	5.14	11.29
27	6.33	6.58	10.17
28	5.47	4.45	12.71
29	7.14	5.74	10.01
30	8.01	6	12.65
Average	**7.20**	**5.73**	**10.23**

Table - 2

ARI SCORES

Sample	Group A	Group B	Group C(control)
1	1	2	2
2	1	3	2
3	1	1	1
4	1	2	2
5	1	3	1
6	1	2	2
7	1	1	2
8	1	2	1
9	1	2	3
10	1	2	3
11	1	2	2
12	1	2	2
13	1	2	2
14	1	2	3
15	1	1	1
16	2	1	2
17	2	2	2
18	1	2	3
19	1	1	2
20	1	1	1
21	1	2	2
22	1	2	2
23	1	1	2
24	1	2	2
25	1	3	2
26	1	2	2
27	2	1	3
28	1	1	2
29	1	1	2
30	1	1	2

Table -3

One way ANOVA for Bond Strength (Mpa)

Groups	N	Mean	Std. Deviation	F-value	P-value
Opal Seal (Group A)	30	7.204	2.524	33.672	**<0.001**
Transbond MIP (Group B)	30	5.727	1.754		
Transbond XT (Group C)	30	10.225	2.145		
Total	90	7.719	2.850		

Table - 4

Independent samples T-Test for Bond Strength (Mpa)

Group	N	Mean	SD	t-value	P-value
Opal Seal (Group A)	30	7.204	2.524	2.633	**0.011**
Transbond MIP (Group B)	30	5.727	1.754		

Group	N	Mean	SD	t-value	P-value
Opal Seal (Group A)	30	7.204	2.524	-4.995	**<0.001**
Transbond XT (Group C)	30	10.225	2.145		

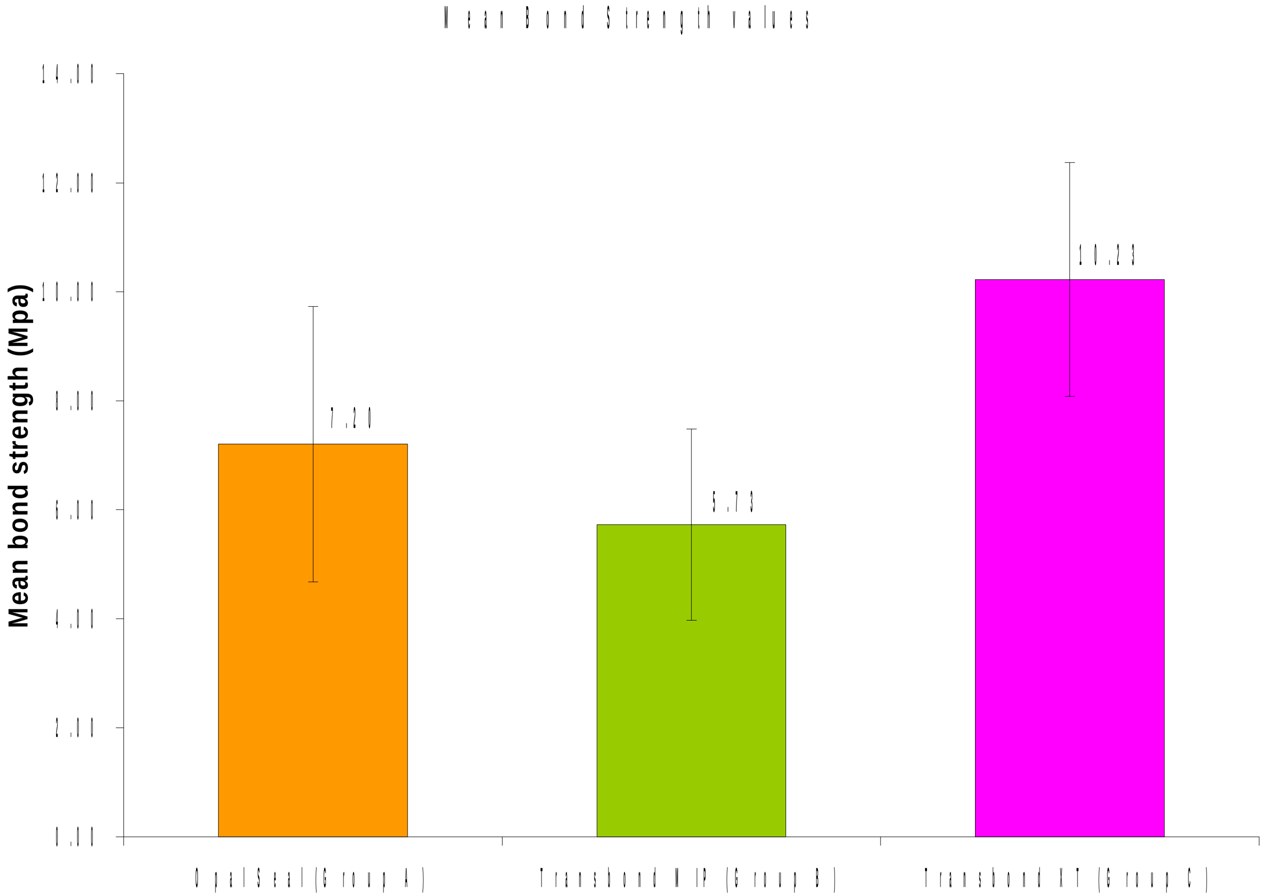
Group	N	Mean	SD	t-value	P-value
Transond MIP (Group B)	30	5.727	1.754	-8.890	**<0.001**
Transbond XT (Group C)	30	10.225	2.145		

Table - 5

ARI Score - Group Cross tabulation and Chi-Square value

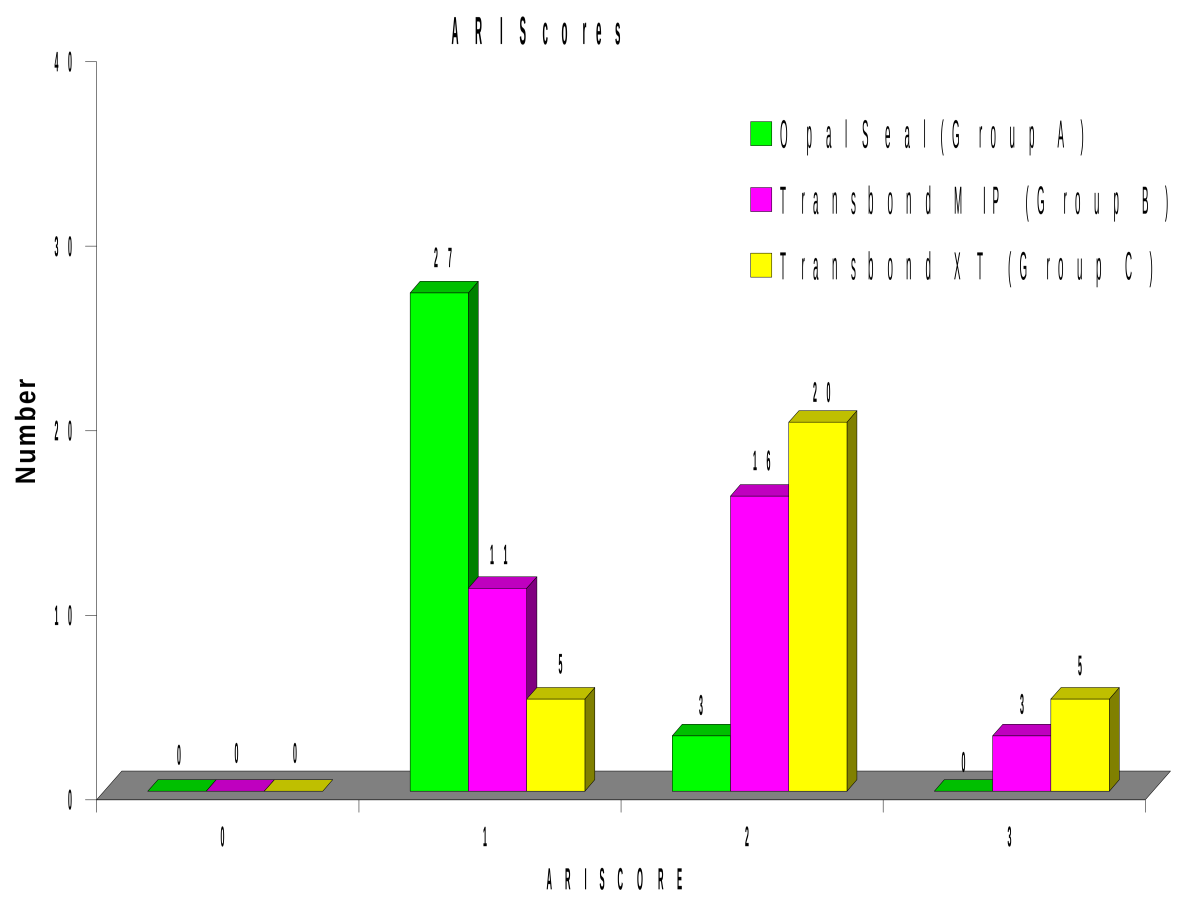
ARI Score	Groups			Total	Chi-Square value	P value
	Opal Seal (Group A)	Transbond MIP (Group B)	Transbond XT (Group C)			
	n (%)	n (%)	n (%)	n (%)	34.95	**<0.001**
0	0	0	0	0		
1	27 (90.0)	11 (36.7)	5 (16.7)	43 (47.8)		
2	3 (10.0)	16 (53.3)	20 (66.7)	39 (43.3)		
3	0 (0.0)	3 (10.0)	5 (16.7)	8 (8.9)		
Total	30 (100.0)	30 (100.0)	30 (100.0)	90 (100.0)		

GRAPH - 1



Mean Bond Strength values
Mean bond strength (Mpa)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
7.20
5.73
10.23
Opal Seal (Group A)
Transbond MIP (Group B)
Transbond XT (Group C)

GRAPH - 2



ARI Scores
Opal Seal (Group A)
Transbond MIP (Group B)
Transbond XT (Group C)
Number
40
30
20
10
0
27
11
5
3
16
20
0
3
5
0
0
0
0
1
2
3
ARI SCORE

Discussion

DISCUSSION

Although the direct bonding of orthodontic brackets has dramatically improved the clinical practice of orthodontics, moisture contamination still poses a problem, especially while bonding posterior teeth and in cases of surgically exposed teeth. Many devices on the market accomplish this like lip expanders and cheek retractors, saliva ejectors, tongue guards with bite blocks, salivary duct obstructers like Dri-Angles, cotton or gauze rolls ,antisialagogues etc.Tablets[31] and injectable solutions[25,170]of different antisialagogues preparation like methanthelene bromide (Banthine), propantheline bromide (ProBanthine) and atropine sulphates are available. Recently council of Dental therapeutics of American dental association has recommended propantheline bromide[170] not to be injected in patients who can take the oral form.

But the modern adhesives, the result of decades of research in restorative dentistry[18,53,55,170] , has eliminated the use of these medications and the inadequacies of those devices regarding moisture control. The changes in the different generations of bonding systems have progressed from etching enamel to etching-conditioning dentin, smear layer treatment, and altered handling properties of adhesives[129]. But bonding such attachments using regular primers in moisture contaminated areas, like bonding partially erupted teeth, lingual bonding, bonding impacted teeth etc, in routine orthodontic bonding procedures is still difficult. Complete isolation cannot be obtained due to the presence of moisture. With the advent of hydrophilic bonding materials, successful orthodontic bonding on a moisture contaminated enamel surface is made easy. The primer solution is a combination of monomers and solvents whose function is to carry resin monomers into the collagen network, previously exposed by acid conditioning, at the same time that it displaces moisture from the dentin /enamel surface via solvents; this creates a resin-reinforced layer known as hybrid layer[1].

The generational improvements in bonding primers for restorative dentistry, listed by characteristic, surface treatment, and properties, respectively, are as follows: first generation, N-phenylglycine and glycidyl methacrylate (NPG-GMA),etched enamel, and dry bonding; second generation, bis-GMA/HEMA, etched enamel, and dry bonding; third generation, 4-META/BPDM, etched enamel surface, and dry bonding; fourth generation, hydrophilic primer, etched enamel/dentin, and wet bonding; and fifth generation, 1-bottle systems, etched enamel/dentin, and wet bonding.

The primer solutions may play an important role on adhesion when dry etched enamel contaminated with saliva or water is considered. Studies on beginning of this decade have suggested that the etched enamel is less sensitive to contamination when new generations of adhesive resins are used. The water chasing ability of primer solutions may provide a beneficial effect on adhesion to enamel by reducing the water content on the contaminated enamel surface, as demonstrated by **Jain and Stewart**[79] (2000).

Bonding in a moist environment or wet bonding was achieved in the fourth generation and applies to orthodontic bonding. Initially hydrophilic primers were used for dentin bonding in restorative dentistry, but now hydrophilic enamel primers have been introduced in orthodontic bonding to display moisture from enamel surface and isolated for bonding. Although traditional Bisgma resins are hydrophobic and are not efficient in a wet environment, MIPs have been used and found to offer comparable strength under both dry and wet conditions[39,67,71,149]. These primers are adaptations of dentin-bonding agents, which have hydrophilic components such as HEMA, which allows a lower contact angle and an extension of the molecule, which readily bonds to the resin composite. It is even more effective when dissolved in acetone solvent. Although enamel has a lesser organic content than dentin, the same principle has been successful.

Moisture insensitive primers are hydrophilic because they contain hydrophilic components such as HEMA (2-hydroxyethyl methacrylate), polyalkenoate copolymers with carboxylate groups, and ethanol. HEMA allows a lower contact angle and an extension of the molecule, which readily bonds to the resin composite. They also contain BISGMA which reinforce the bond strength and unfilled resin that help penetrate the etched surface of tooth. Although enamel has lesser organic content than the dentin, the same principal is successful. (**Hobson**[77]**, Grandhi**[67]**, Webster**[101] et al 2001). According to studies by **Mark J.Webster**[101], **Ram Kumar Grandhi**[67] **and Ross S. Hobson**[77] hydrophilic bonding materials like MIP can be used in difficult areas of bonding where control of moisture will be difficult and the use of these materials were found to be more effective when compared to the acetone Primers.

Therefore, Transbond MIP was used in this study to bond on contaminated enamel surfaces of the teeth. Another new material which has been advocated for bonding in moist environment is Opal Seal, which is supposed to posses more or less similar properties like MIP according to the product literature available from manufacturer. Both Transbond MIP and Opal Seal are ethanol based primers. The hydrophilic monomer in Opal Seal contains HPMA instead of HEMA in Transbond MIP. In addition Opal Seal has the ability to release fluoride and recharge due to the presence of glass monomer.

According to manufacturer, Opal Seal is an orthodontic light cure bonding primer which releases fluoride and recharges fluoride uptake. Opal seal is 38% filled with substantial glass ionomer and nano-fillers which contains hydroxypropyl methacrylate (HPMA) as a hydrophilic monomer and ethyl alcohol as drying agent. Hydroxypropyl methacrylate (HPMA) has lesser solubility and molarity(0.067± 0.01) when compared to HEMA which is miscible in all proportions[23]. The drying agent seeks out moisture, evaporates it from the bonding field and draws resin in, ensuring reliable, consistent bonding. The nano-fillers penetrate even to the tiniest fissures, creating the most secure bond. According to the manufacturer Opal Seal has an added advantage that it contains GIC which can release and recharge fluoride to minimize white lesions. Opal Seal's non-yellowing formulation resists staining and is translucent under a UV Black light because of its fluorescing properties which facilitate removal and re-application. Opal Seal features a specially designed, disposable tip that employs a spiral canal to accurately and economically deliver filled resins in a thin, uniform layer. The main advantage of Opal Seal is being compatible with any bonding system.

The immediate bonding effectiveness of contemporary adhesives is quite favourable, regardless of the approach used. In the long term, the bonding effectiveness of some adhesives drops dramatically, whereas the bond strengths of other adhesives are more stable. Because of the fact that orthodontic adhesives are routinely exposed to thermal changes in the oral cavity, it is paramount to establish whether these changes introduce stress in the adhesive that might affect bond strength. Thus, any new adhesive should be tested both at 24 hours of storage in water and after thermal cycling[21]. Thermal cycling is the in vitro process through which the adhesive resin and the tooth are subjected to temperature extremes compatible with the oral cavity[76]. During the thermocycling test the samples are subjected to thermal changes and additional water exposure. The artificial aging effect induced by thermo-cycling can occur in two ways:

(1) Hot water may accelerate hydrolysis of interface components, and subsequent uptake of water and extraction of breakdown products or poorly polymerized resin oligomers (**Miyazaki et al.**[112]**,** 1998; **Hashimoto et al**[74]., 2000); or

(2) due to the higher thermal contraction/expansion coefficient of the restorative material (as compared with that of tooth tissue), repetitive contraction/expansion stresses are generated at the tooth-biomaterial interface. These stresses may lead to cracks that propagate along bonded interfaces, and, once a gap is created, changing gap dimensions can cause in- and outflow of oral fluids, a process known as 'percolation' (**Gale and Darvell**[64]**,** 1999).

The decrease in bond strength after thermocycling can also be attributed to increased water absorption or solubility of the composite, or both. **Gale** and **Darvell**[64] pointed to the absence of agreement and standardization between the various thermocycling studies. Different thermocycling regimens were used in in vitro studies investigating the effectiveness of hydrophilic primers .The main difference among these studies was in the number of thermal cycles (500, 750, 1500, and 2500). At the same time, the temperature extremes were different. The low-temperature points were 5^0C or 10^0 C, and the high-temperature points were 45^0C, 50^0C, or 55^0C. Nevertheless, in these studies the thermocycled samples were not compared with nonthermocycled samples as recommended by **Bishara et al**[21].

Thermocycling has been recommended by **Buonocore[30]** and **Zachrisson[175]** to reflect the effect on bond strength of long-term immersion under oral moisture conditions. Studies by **Tjan et al[161].; Dietschi and Herzfeld[44]; Pilo and Ben-Amar[131]; Frankenberger et al[60] ; Meiers and Young[107], and Cardoso et al[33]** showed that all specimens are 'aged' (by, for example, thermo-cycling) so that more 'clinically' relevant data can be obtained. Various methods[86] by which aging achieved are,

5. Aging by storage[88,150]
6. Aging by thermo-cycling[64,80]
7. Aging by occlusal loading[91,121]
8. Combination of all

Bishara[21] et al have stated that "the purpose of thermocycling was to subject the teeth to the temperature changes that may occur in the oral cavity."They also found clinically accepted bond strength value (10.99± 3.34 MPa) for Assure hydrophilic primer under wet condition using natural saliva.

To our knowledge no studies have been conducted on the effect of thermocycling and comparing the bond strength of hydrophilic primers like Transbond MIP and Opal Seal which are suitable for orthodontic bonding, in moisture or saliva contaminated areas.

The aim of the present study were

1. To evaluate and compare the shear bond strength after thermocycling, of newly introduced hydrophilic material Opal Seal with a well studied moisture insensitive primer Transbond MIP and Transbond XT, as the (control group).

2. To compare the adhesive-failures locations between three primers - Opal Seal (Group A), Transbond MIP (Group B) after contamination with saliva and Transbond XT (Group C- control group) without saliva contamination .

In the present study, 90 extracted human upper and lower premolar teeth were taken and divided into 3 main groups (Group A- Green, Group B- Yellow and Group C-Orange). Each group contained 30 teeth. Various storage media have been used to store teeth like water, saline, artificial saliva, thymol, 10% formalin etc, and in this study, all teeth were stored in 10% formalin at 37°C as suggested by **Nigela A.Fox**[120] ,as the storage media does not alter the bond strength. Another advantage of storing in 10% formalin is that it prevents the growth of potentially harmful bacteria and thus more hygienic.

Prophylaxis is done to remove the debris, plaque, oil, impurities and organic pellicle on the surface enamel, which is said to resist acid penetration. Enamel loss with rubber cup prophylaxis is considered less destructive (5.0µ) when compared to bristle brush prophylaxis (7.0 µ) --**Pus and Way**[133], hence in the present study rubber cup prophylaxis with pumice was done on all the teeth.

Bond strength to enamel can be enhanced by acid-etching the surface. The adhesion to the enamel substrate relies on micro-mechanical retention which is assumed to be a function of increased microporosity and high surface energy. These factors improve the superficial wettability for bonding agents and lead to the formation of tag-like extensions within the enamel[29].

Various solutions have been proposed for acid etching—**Buonocore[27]** first introduced phosphoric acid in 1955 to increase the adhesion of acrylic filling material to the tooth surface. Polyacrylic acid[57,98], Nitric acid[15], Maleic acid[73] and Sulphuric acid[9] have all been tried for etching and it has been found that the depth of penetration of etchants at all concentrations were significantly less than that of phosphoric acid despite producing surface regularities. Laser etching was also compared to chemical etching and was considered inferior to orthophosphoric acid as suggested by **Akhikio et al[2]**. As orthophosphoric acid is the standardized acid used, the same has been used in this study to etch the enamel surface.

Various modifications have been put forward to improve the efficacy of etching action of orthophosphoric acid by varying the etch time and acid concentration of orthophosphoric acid. According to **Bishara et al[20]**, a higher bond strength was achieved because 37% phosphoric acid produces a qualitatively rougher enamel surface.

In this study, three types of primers were categorized into Group A (Opal Seal–Green) , Group B (Transbond MIP –Yellow), Group C (Transbond XT- Orange). Two different types of hydrophilic primers (Group A- Opal Seal and Group B- Transbond MIP) that were used are both ethanol based primers. Ethanol has the property to diffuse very easily into water. Therefore it demonstrates higher bond strength when used on contaminated wet enamel surfaces compared to that of acetone based primers. Acetone based primers do not easily get diffused in water as far as enamel bonding is concerned and thus produce lesser bond strength when compared to ethanol based primers. Transbond MIP and Opal Seal being ethanol based primers, gets diluted more easily when used on wet enamel surface unlike when compared to acetone based primer like Prime , Bond NT or Transbond XT. Transbond XT(Group C) was used as control in this study.

Stainless steel premolar brackets (0.022 slot Roth, Mini 2000 series, Ormco) were bonded to tooth surface and cured. The adhesive used in this study is a light cured composite resin adhesive paste Transbond XT (3M Unitek, Monrovia, Calif).

Visible light cure unit (3M Unitek halogen curing light) with wavelength range from 400 to 500 nm was used in the present study. The specimens were cured for 10sec each for the mesial, distal and gingival surfaces and incisally for 10 sec as advocated by **Mark J.Webster**[101]. After bonding, the teeth were stored in distilled water at 37°C for 48 hours.

Even though various artificial aging methods are available in present study we included thermocycling to mimic aging of adhesives. After bonding all the samples were stored in distilled water in sealed container at room temperature for 48 hrs and then thermocycled (500 x) between 5ºC and 55ºC[80], with a dwell time in each bath of 30 seconds and a transfer time between baths of 15 seconds in Willitech thermocyler with cooling system, Haake EK 30, Thermoelectron corporation, Germany.

Various debonding methods can be used to debond a bracket from a tooth using pliers, **Perry** [129]1980, chateltton model DTC Universal Tester **Newman**[118], MTS testing machine **Nigela**[120]which are similar to Universal Testing Machine like Lloyd and Instron Machine. In the present study Universal Testing Machine (INSTRON 3365, UK) was used to assess shear bond strength. After 48 hours the specimens were mounted on an Universal testing machine (INSTRON 3365, UK) set at a cross head speed of 1mm/min. To standardize the direction of the debonding force, each specimen was mounted in acrylic blocks in this study. However, **Fox** et al [58]cautioned that a pure shear test might not be ensured, and factors such as the curvature of the enamel surface might influence the results. A wire loop was placed around the wings of the bracket to evaluate the shear bond strength.

The bracket base surface area was given by manufacturer and measured with a digital caliper as 9.63 mm^2. Bond strength were accurately calculated and expressed as Mpa, after the assessment of the bond surface area, which was found to be 9.63mm^2. Values of failure loads (N) were recorded and converted into megapascals (MPa) by dividing the failure load (N) by the surface area of the bracket base (9.63 mm^2). **Retief**[136] (1974) highlighted the different factors with respect to optimal bond strength. He showed that enamel fractures can occur with bond strengths as low as 138 kg/cm2 (13.53 MPa). It is comparable with the mean linear TBS of 148 kg/cm2 (14.51 MPa) for enamel reported by **Bowen and Rodriguez**[23] (1962). The minimum clinically adequate TBS according to **Reynolds**[138] (1975) appears to be between 60 and 80 kg/cm2 (5.88-7.85MPa). It was also shown by **Bishara et al**[17] (1993) that a mean safe debonding strength should be less than 115 kg/cm2 (11.28 MPa). Thus the optimum range is thus between 5.88 and 13.53 MPa.These bond strengths are considered to be able to withstand various tensile load[47]. There is a wide variation in the bond strength values for orthodontic adhesives in the literature. Previous studies using Transbond MIP primer with Transbond XT resin adhesive have reported bond strengths ranging from 10.4 Mpa to 20 Mpa[44,101,144]. The results of the present study indicate that after thermocycling, the mean shear strengths required for bond failure with Group A (Opal Seal – Green), Group B (Transbond MIP –Yellow),Group C (Transbond XT- Orange) is 7.2 Mpa, 5.73 Mpa and 10.23 Mpa respectively. So the mean bond strength of Opal Seal which was well above the clinically acceptable bond strength value indicating the use of this hydrophilic bonding material in contaminated environments as depicted in various studies[44,101,144]. Opal Seal showed considerably higher bond strength than Transbond MIP which showed a lower value than clinically accepted bond strength.

The results obtained from this study were subjected to statistical analysis viz; analysis of variance – one way ANOVA and intergroup comparison done with Independent sample T- test. The results suggested that there is statistically significant difference in the mean values of Mpa between ($p <0.001$) and within the groups ($T < 0.011$) . The Independent sample T- test depicts that statistically significant difference in bond strength Mpa values between the group A and group B ($T = 0.011$) whereas there is high statistically significant difference in bond strength Mpa values($T < 0.011$) between the group A and group C and between the group B and group C.

Therefore, the mean bond strength of Group A (Opal Seal) showed greater bond strength values when compared to that of Group B(Transbond MIP – 5.727 Mpa) which is 7.204 Mpa. The difference in bond strength between Group A (Opal

Seal) and Group B (Transbond MIP) was found to be statistically significant (T = 0.011). The bond strengths obtained with both types of hydrophilic primers in this study, in wet conditions were found to be lower than that of the control group in dry condition. But Opal Seal (Group A) showed clinically acceptable bond strength in wet condition even after thermocycling where as Transbond MIP showed a lower range of clinically acceptable bond strength.

To our knowledge there is no studies done for the comparison of MIPs containing HEMA with MIPs containing HPMA used for orthodontic bonding. So we are comparing our result with other studies done on MIPs containing HEMA.

Grandhi et al[67] evaluated the bond strengths of conventional Transbond XT primer (11.06 ±1.49 Mpa) and Transbond MIP primer (10.14 ± 1.22 Mpa) in dry-etched conditions using bovine teeth. But they found statistically significant higher bond strength for Transbond MIP (8.90 ± 0.62 Mpa) than Transbond XT (1.51 ± 0.37 Mpa) in wet etched condition using fresh saliva. In the present study, using human premolars, similar bond strength value obtained for conventional Transbond XT primer (10.22 ± 2.14Mpa) in dry-etched conditions. But the Transbond MIP primer (5.73 ± 1.75 Mpa) in wet etched condition using artificial saliva showed less bond strength in present study which may be due to the artificial aging done to the samples.

Littlewood et al[96] reported lower bond strength with the fifth-generation MIP primer (6.43 Mpa) compared with a conventional primer(8.71 Mpa) in dry condition using APC bracket on human premolar. The bond strength values are greater than present study values. So, in contrast to **Littlewood et al**[95], bond strength found in the present study was at a lower range of clinically acceptable bond strength. It may be because of the artificial aging treatment done by thermocycling in present study.

Douglas Rix et al [45] found a bond strength value of 20.19 Mpa for Transbond XT under dry condition which significantly higher than the present study value (10.23 ± 2.15Mpa).The teeth selected were subjected to a thermocycling procedure, in 2 thermally controlled streams of water maintained at 10°C and 55°C for 24 hours after the 30-day incubation period. **Bishara[21] et al** have stated that "the purpose of thermocycling was to subject the teeth to the temperature changes that may occur in the oral cavity."They also found bond strength values (10.99± 3.34 MPa) of Assure hydrophilic primer under wet condition using natural saliva. Compared to the present study this SBS value for hydrophilic primer is significantly high.

Shane Schaneveldt[144] et al showed higher bond strength for both the conventional Transbond XT primer (14.82 ±2.62 Mpa) in dry-etched conditions and Transbond MIP primers(12.23 ± 2.53 Mpa) in wet etched condition than the bond strength values obtained in the present study (10.22 ± 2.14Mpa and 5.73 ± 1.75 Mpa respectively). They followed the surface treatment sequence of etch, Rinse/dry, saliva, Primer, Composite ,Visible light cure similar to present study in some of the sample group except that they used natural saliva. This sequence was called as "prepriming". In addition, they have done thermocycling procedure in 2 thermally controlled streams of water maintained at 10°C and 55°C for 24 hours. In the same study, some of the sample group they have primed with MIP first and then was applied a thin coat of natural saliva over the primer. Another thin coat of MIP was applied over this wet surface and then cured the bracket with adhesive. This method was called as “intra priming”. They showed higher bond strength values for intra priming group (14.02 ± 2.94 Mpa) than prepriming group. This value is also higher than the “prepriming” bond strength value of the present study.

Mark J.Webster et al[101] showed a mean bond strength of Transbond XT with MIP is 20.72 ± 4.61 Mpa after surface treatment sequence of etch, Rinse/dry , Artificial saliva, Primer , Composite ,Visible light cure of bovine teeth . Although the study is done in vitro following the sequence of surface treatment similar to the present study the bond strength values are higher.

Rangaswamy Rajagopal et al[135] showed maximum bond strength of Self-etch primer compared to that of conventional and MIP primer under both dry (11.104 ± 2.56 Mpa) and wet conditions(10.79 ±2.43 Mpa) contaminated with natural saliva. Conventional primer was comparable with the former under dry conditions(9.54 ±3.86 Mpa) but did not offer clinically adequate bond strength in cases of moisture contamination(4.69 ±3.10 Mpa) .Both MIP (9.07 ±1.99 Mpa) and self-etch primer showed adequate bond strength superior to that of conventional primer in case of moisture contamination. In present study the conventional primer gave more bond strength under dry condition but both the moisture insensitive primers showed less bond strength. But among hydrophilic primer, Opal Seal showed clinically acceptable bond strength.

Andreas Faltermeier et al[6] (2007) evaluated the shear bond strength of a conventional primer (Transbond XT) and a moisture-insensitive primer (Transbond MIP) under dry conditions and after contamination with natural saliva, blood and etching gel remnants after thermocycling(6000× 5°C/55°C) in a mastication device to simulate temperature changes and the moisture of saliva in the oral cavity. Under dry conditions Transbond XT (8.71 ± 1.37 Mpa) and Transbond MIP (9.29 ± 1.16 Mpa) showed no significant difference in SBS. However, clinically unacceptable bond strength was observed using Transbond XT after saliva (3.42 ± 0.78 Mpa) blood (2.37 ± 1.13 Mpa) and etching gel (8.47 ± 0.78 Mpa) contamination. In wet conditions only Transbond MIP showed sufficient bond strength in saliva (8.82 ± 1.21) blood (7.08 ± 0.78) and etching gel (9.16 ± 0.95 Mpa). The bond strength value in this study is greater than the bond strength values of Transbond MIP in present study. But Transbond XT showed more bond strength in present study.

Zeppieri[81] investigated the effect of saliva contamination on the shear bond strength of Transbond Moisture-Insensitive Primer and Transbond Plus Self-Etching Primer. Transbond XT primer was used as a control. Brackets were bonded with Transbond XT adhesive similar to present study. Shear bond strength of Transbond XT primer (21.3 ±6.8 MPa) under dry-etched condition and that of Transbond MIP (15.0 ± 3.0 MPa) under etched-wet condition is higher than that of present study which may be due to the artificial aging done in present study.

Endo T[52] evaluated the effects of different degrees of water contamination on the shear bond strength of orthodontic brackets bonded to dental enamel with a moisture-insensitive primer (MIP) adhesive system. Human premolar were taken and enamel surface condition is done- desiccated, blot dry, and over wet before applying Transbond MIP primer. The bond strength values of over wet group were significantly lower than that of other groups and also lower than the clinically required values. So, they concluded that to achieve clinically sufficient bond strengths with the hydrophilic MIP adhesive system, excess water should be blotted from the water-contaminated enamel surface. In the present study, following the instruction of manufacturer Transbond MIP is coated on entire buccal etched surface avoiding the gingival area. Then each tooth was air bursted gently for 3 seconds (2-5 seconds instructed by manufacturer) perpendicular to the buccal surface. Opal Seal was also coated same way following manufacturer's instruction which is similar to Transbond MIP. The bond strength values of Opal Seal group in present study were obtained higher than clinically required values supporting the conclusion of this study.

Thus the different bond strengths obtained in these studies could have been due to the differences in the fields of bonding, testing and handling the materials by the operator along with the artificial aging done to the samples.

The Adhesive Remnant Index provides an easy method of evaluating adhesive remnants following debond. **O'Brien et al**[123] claimed that the ARI score depended on many factors, including the bracket base design and the adhesive type, and not simply on the bond strengths at the interfaces. Various other studies have shown that the ARI score depends on

- -The type of adhesive used
- -Position of the tooth within the arch
- -Method of bracket removal
- -Bracket base material

Furthermore, ARI values are subjective. Nevertheless, the index was useful in determining the percentage of bond-failure sites. In this study the residual resin on the tooth surface after debonding was evaluated with Adhesive Remnant Index (ARI), developed by **Artun and Bergland** [9] which is a 4 point scale to quantify the amount of adhesive remaining on the tooth surface.The debonded surface was examined under a magnification of 16X.

The **ARI** chart shows

0 - No adhesive remaining on the tooth surface

1 - less than half the adhesive remaining on the tooth surface.

2 - More than half the adhesive remaining on the tooth surface.

3 - All the adhesive remaining on the tooth surfaces with the impression of the bracket base.

In present study , a non parametric Chisquare Test was done to rank the ARI score for all 3 groups. Chi square test values obtained for all 3 group are 34.95 with p value <0.001. Adhesive remnant index showed a statistically significant difference between the groups.

When the ARI score was done for the present study, it was observed that, among the three groups, the teeth which were bonded in dry environment had the highest ARI score whereas, the teeth which were contaminated with artificial saliva had the lower ARI score. It might be due to the larger amounts of contaminated components, organic and inorganic substrates in saliva, remaining on the etched surfaces and preventing complete penetration of the primer[82]. **Itoh et al**[83] reported that insoluble saliva proteins and minerals compromise the setting of the cements. The high viscosity of saliva might occlude the microscopic roughness produced by etching and inhibits proper resinous tag formation.

Ninety percent(90%) of the teeth bonded with Opal Seal and 36.7 % of the teeth bonded with Transbond MIP and 16.7% of the teeth bonded with Transbond

XT demonstrated a lowest ARI score of 1, suggesting more frequent failure between adhesive and enamel and thus producing a more chance to damage the enamel. But cleaning up procedure will be easier.

Ten percent(10%) of the teeth bonded with Opal Seal,53.3% of the teeth bonded with Transbond MIP and 66.7% of the teeth bonded with Transbond XT demonstrated a higher ARI score of 2, suggesting more frequent bond failure within the adhesive, indicating that there was no damage to the enamel but the clean up procedure was more.

Ten percent(10%) of the teeth bonded with Transbond MIP 16.7% of the teeth bonded with Transbond XT demonstrated ARI score index of 3 ,thus suggesting a failure between the adhesive and bracket base indicating that there was no damage to the enamel but the clean up procedure was more time consuming and abrasive to enamel.

Type of bond failure obtained in present study differs to that found by **Endo T et al**[52]. **Shane Schaneveldt et al**[144]**.**

Eliades[49] **et al** investigated site of bond failure with the help of fractography of enamel and bracket base surface. They found that Transbond MIP in conjunction with a no-mix adhesive (Unite) showed adhesive fractures (leaving no resin on enamel surface), whereas Smartbond presented more of cohesive fractures (adhesive left on bracket and enamel surface).Thus this result differs from our study.

The bond strength of attachment must be sufficient to withstand functional forces but at a level to allow bracket debonding without causing damage to the enamel, which may occur when bond strength exceeds 14 Mpa[129]. There is no reliable protocol for estimating the in vivo bond strength of orthodontic bonding system[49]. The bond strength observed in an in vitro study may be higher than those witnessed clinically. However, in vitro studies provide a guide in selection of bracket/ adhesive[129]. The universal testing machine is capable of measuring pure shear forces; however there is shear, tensile and torsional forces present during in vivo bonding. In addition, the rate of loading for the machine is constant, whereas it is not standardized or constant in in-vivo debonding.

The limitation of this study are this being an in vitro study, this does not truly reflect the oral environment. The forces like masticatory, occlusal stress and other many factors which could modify the bond strength of hydrophilic primer could not be simulated in this study. This study was done on maxillary and mandibular human premolar teeth and it was not tested on other teeth like, incisors and molars where the chance of moisture contamination is very high. Only the buccal surfaces of the premolar teeth have been taken into consideration in this study, in future the study must also be performed on lingual surfaces to evaluate the bond strength when attachments other than brackets are used for bonding, especially with wires that are used as fixed lingual retainers. Therefore, further studies should be done under in vivo conditions to assess the bond strength of this material. The teeth collected were not from a particular age group, hence the age of the patient was not taken into consideration in this study. Studies should be performed in young permanent and partially erupted teeth, evaluating the bond strength on such teeth with the presence of a prism-less layer on surface will reduce the retention, (**Der Hong, Sheen and Wei Nan**[43]). Moisture contamination is very common when bonding attachments to partially erupted young permanent or surgically exposed teeth. The bond strength in older permanent teeth is greater than that of the younger teeth because recently erupted teeth are completely covered with pronounced perikymata and rod-ends. With age, the perikymata and rod-ends may wear away. As a result of age changes in the organic portion of enamel presumably near the surface, teeth may become harder and thereby reinforce the bond strength.

Therefore, this material should be tested on young permanent and erupting teeth, as these teeth are covered by a prism-less layer thus indicating reduced retention when compared to the permanent teeth.

Ozcan et al stated that when no or limited thermocycling was performed, high bond strengths can be found that do not correspond to chair-side experiences. Selma et al evaluated SBSs of self etching primer (contains hydrophilic monomer) for 2000 and 5000 thermal cycles and found a significant difference from SBS obtained for 0 or limited thermal cycles. To achieve artificial aging one should include all the aging processes which are aging by storage, aging by thermo-cycling and aging by occlusal loading.

According to the manufacturer Opal Seal has the ability to release fluoride and recharge due to the presence of glass monomer. Further studies should be done for better understanding on this ability of Opal Seal.

In vitro studies provide very important data concerning the physical and mechanical properties of a material, but the final evaluation can only be provided when we assess these materials under clinical conditions. Hence extensive clinical trials over extended period are needed to be performed in order to evaluate the performance of this material in clinical situation.

Summary and Conclusions

SUMMARY AND CONCLUSION

The present study was undertaken to evaluate the effectiveness of Moisture Insensitive Primers (Transbond MIP and Opal Seal MIP-etched/wet) with Transbond XT primer (etched/dry) as the control used along with Transbond XT adhesive, by comparing their shear-peel bond strengths after thermocycling. After debonding of the bracket, the surfaces of the teeth and bracket bases were examined to assess the Adhesive Remnant Index (ARI) and adhesive-failures locations.

Based on the statistical results derived from this study, the following conclusions were drawn.

1. Among hydrophilic primers tested, the bond strength produced by Group A product Opal Seal (7.2 ±2.52 Mpa) was higher than that of Group B product Transbond MIP (5.73± 1.75 Mpa), which was statistically significant.

2. Both the tested groups showed lesser bond strength values than Transbond XT (10. 26 ± 2.14 Mpa) the control Group C.

3. Transbond MIP showed a lower range of bond strength (5.73± 1.75 Mpa) compared to optimal bond strength (5.88 - 13.53 Mpa) whereas the Opal Seal showed the range well within the optimal bond strength (7.2 ±2.52 Mpa).Therefore Opal Seal is a good viable option to use as a moisture insensitive primer clinically.

4. ARI scores revealed that there is significant difference in the site of bond failure between different groups. Lower ARI scores suggesting more frequent failure towards adhesive and enamel for Group A(Opal Seal) compared to higher ARI score suggesting more frequent failure towards adhesive and bracket base for Group B (Transbond MIP) and Group C (Transbond XT).

5. Even though both Group A and Group B (Transbond MIP) showed cohesive failure, Group A had less adhesive remnant remaining on the enamel surface. Therefore, the tooth clean up procedure after debonding was easier and faster for Group A (Opal Seal) when compared to Group B (Transbond MIP) and Group C (Transbond XT).

According to the manufacturer Opal Seal has the ability to release fluoride and recharge due to the presence of glass ionomer filler particles. Further studies should be done for better understanding on this ability of Opal Seal.

Many factors in the oral environment are impossible to reproduce in the laboratory. Hence to have values of clinical significance between bonding systems, in vivo research must be carried out to confirm laboratory results.

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